ECOLOGICAL CORRELATES OF RARE CAPE PROTEACEAE,

SOUTH AFRICA,

AND THE IMPLICATIONS FOR THEIR CONSERVATION.

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Thesis submitted to the Faculty of Science,

University of Cape Town,

for the degree of Master of Science.

November 1988

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ABSTRACT

ABSTRACT

This thesis examines the ecology of rare Proteaceae of the Fynbos Biome, South Africa. The aim was to determine whether there are any unifying ecological parameters which might be significant for their conservation. The current status of all Cape Proteaceae was initially assessed. A total of 124 taxa were ascribed the I U C N status of recently extinct (3 taxa), endangered (33 taxa), vulnerable (29 taxa), and naturally rare (59 taxa). The distributions of rare taxa are characteristically small in size and range, 59 taxa occurring in only one or two populations and 63 taxa being restricted to a range of less than 5 km^2. Small nature reserves are proposed for the protection of such restricted taxa. An examination of the distribution of all the rare taxa shows exceptionally high concentrations in the Cape Town urban area and the lowlands north of Cape Town. This indicates the need for conservation considerations by urban and regional planners in the long term development of this area. Naturally rare taxa exhibit n-odes (areas of high concentrations) over the centres of well defined centres of endemism. Such areas merit conservation as representative and diverse habitats of fynbos plant species. Threats occurring at rare Proteaceae sites were recorded. An inappropriate fire interval and invasion by the Argentine ant, *Iridomyrmex humilis*, were shown to be the probable cause of rarity in Proteaceae exhibiting short lifespans and myrmecochorous seed stores. The monitoring of fire intervals at rare Proteaceae sites and the removal of the Argentine Ant are considered priorities for conservation management of rare Proteaceae.

GENERAL INTRODUCTION

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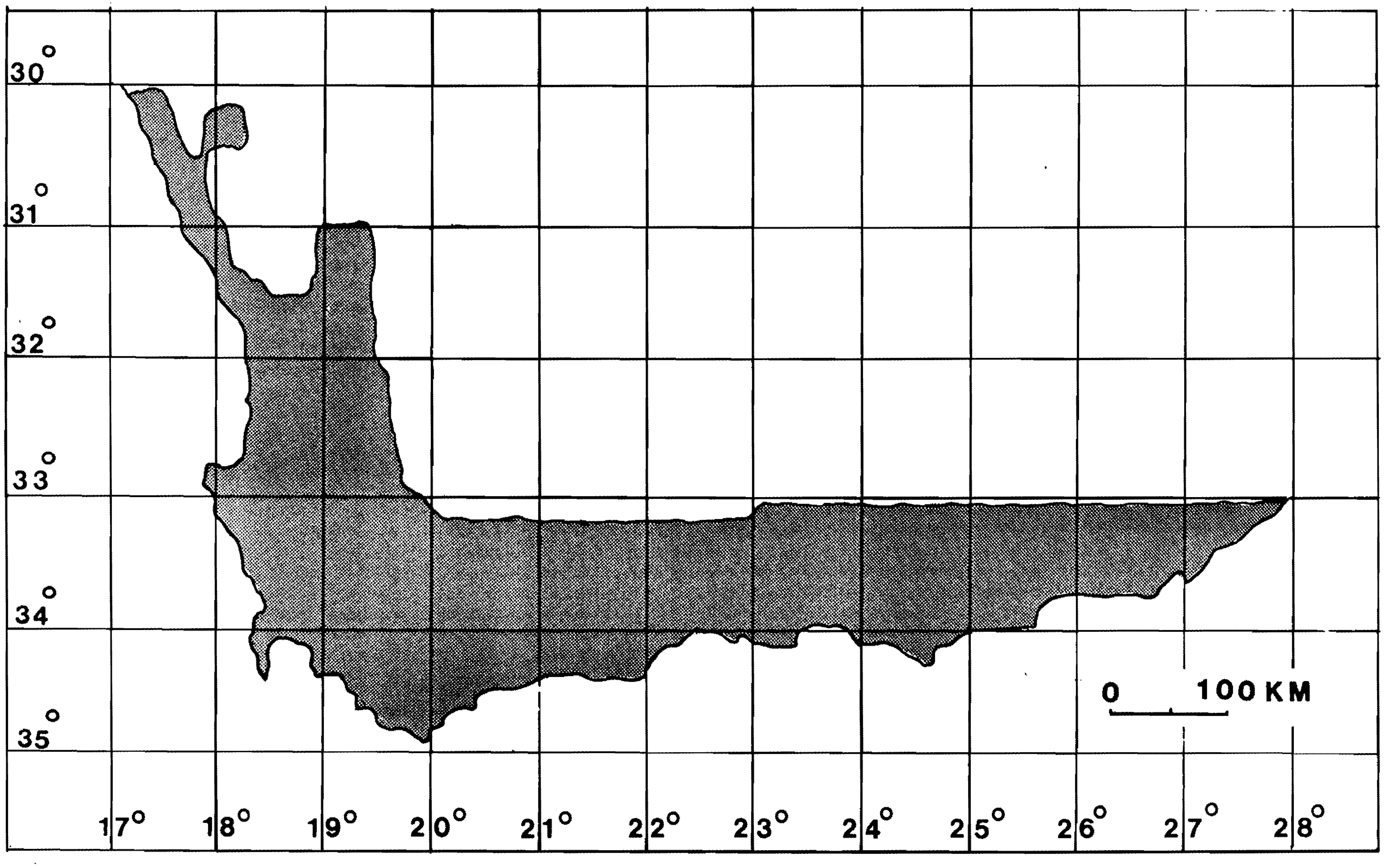
The Cape floristic kingdom is one of six such kingdoms in the world (Takhtajan, 1969). It lies between latitudes 30° and 35 ° S and longitudes 17° and 28° E and is approximated in extent by the fynbos biome as delineated by Moll & Bossi (1984a) (Fig. 1). In area, the fynbos biome covers approximately 90 000 km^2, less than 4% of the land area of southern Africa (Goldblatt, 1978). It differs markedly from the rest of the African flora in terms of vegetation structure, the patterns of adaptation and specialization, the composition of species, genera and families, the rich presence of Proteaceae, Ericaceae and Restionaceae and the endemic families Peneaceae, Stilbaceae, Grubbiaceae, Roridulaceae, Retziaceae, and Geissolomaceae (Bond & Goldblatt, 1984). It is represented by some 8504 species of seed plants (almost 50% of the southern African flora) of which almost 70% are endemic species (Bond & Goldblatt, 1984; Gibbs Russell, 1985) and of which almost 20% are rare (Hall *et al.*, 1984). Moll & Bossi (1984b) have calculated that there has been a loss of 34 % of natural vegetation from the fynbos biome to agriculture, urban expansion and other human related activities since the arrival of European settlers over 300 years ago.

The fynbos vegetation is an evergreen sclerophyllous shrubland (as described by Moll & Jarman, 1984a;b) largely restricted to infertile soils, with a substantial proportion of the region receiving winter rainfall (Moll *et al.*, 1984) of 300 - 2500 mm per annum (Taylor, 1978). The landscape is both rugged and dissected offering a multitude of unique and varied habitats, stretching from the coast to mountain peaks over 2000 m high. Geologically the mountains are mostly of the Table Mountain Sandstone and Witteberg Quartzite groups (Boucher & Moll, 1981). The coastal flats are mostly recent aeolian sands and inland the flats are derived from shales of the Malmesbury and Bokkeveld groups (Taylor, 1978).

FIG 1: The region defined as fynbos biome (after Moll & Bossi, 1984a) for the purposes of this study.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The distribution of the family Proteaceae is largely within the fynbos biome where it constitutes a dominant ecological component (Taylor, 1978). Cape Proteaceae exhibit a high degree of endemism at the generic and specific level, a characteristic typical of many Cape species. The family is represented by 325 taxa in the fynbos biome (Gibbs Russell *et al.*, 1984), and is well known both ecologically and taxonomically (Rourke, 1969; 1972; 1976; 1980; 1984a; b; Levyns, 1970; Williams, 1972), making it an ideal experimental family. Proteaceae have been extensively exploited by the wild flower industry for their unusual and often ostentatious blooms (Vogts, 1982). In addition, the threats of agriculture, fire control and urban development, to name but a few, have left their mark.

Studies on rare plants of the fynbos biome have been limited. For many years the Council for Scientific and Industrial research (CSIR) rare plant survey has been concerned with the identification and enumeration of rare plant species for Southern Africa (Hall, 1987; Hall *et al.*, 1980; Hall & Veldhuis, 1985). This survey has now been discontinued and the data housed in Directorate of the Environment which manages natural areas. Milewski (1978a & b) examined the habitats of 12 rare Proteaceae taxa of the Western Cape coastal flats and concluded that all required different habitats. A somewhat similar study to this one has been completed by Hodgson (1986 a, b, c, d) in the Sheffield flora, United Kingdom. He compared the characteristics of the common and rare taxa of this region and their implications for the conservation of the Sheffield flora. He emphasises the need for a family approach in rare plant studies, an approach used in this study. No similar ecological study of Proteaceae or any other rare taxa has been attempted previously for the fynbos biome. This meant that there were no expected results, and no results to compare with those of the present study.

The term rarity as used in this study is based on the definition offered by Rabinowitz (1981) who gives prime consideration to geographical range, habitat specificity and population size. The categories of rarity used in this project are those defined by the International Union for

Conservation of Nature and National Resources (IUCN) (Synge 1981). The use of IUCN categories of rarity conforms to the system already adopted for describing rare plant species (Hall & Veldhuis, 1985).

The aim of this project was to investigate any potentially unifying ecological parameters associated with rare taxa of Proteaceae which might be of significance in terms of conservation management of rare plants. The specific aims were:-

1) To assess the current rarity status of the Cape Proteaceae.

2) To investigate the population ecology of the rare Cape Proteaceae and its implications for conservation management.

3)To investigate the distribution of the rare taxa and to use this to identify areas for conservation.

4)To record and examine threats known from rare Proteaceae sites.

5)To compare ecological characteristics of rare taxa with those observed in the family as a whole and to attempt to correlate any significant differences with rarity.

The thesis is divided into three broad sections. The first (Chapter 1) discusses the status of the Proteaceae and how this has altered since the previous assessment. The second section (Chapter 2) compares the distribution of the rare taxa in comparison to the total distribution for the Cape Proteaceae. The final section (Chapter 3) examines the threats associated with rare Proteaceae and ranks them according to frequency. Observed patterns within rare Proteaceae were compared to the patterns generally found within the family Proteaceae. Chapter 1 has already been published and Chapters 2 and # are about to be submitted for publication. Although this facilitates rapid dissemination of the data, it inevitably results in some repetition. For convenience, the chapters are in the format of the journals to which they have been or will be submitted. All papers are published under my maiden name, S A Tansley.

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CHAPTER 1

THE STATUS OF THREATENED PROTEACEAE IN THE CAPE FLORA, SOUTH AFRICA, AND THE IMPLICATIONS FOR THEIR CONSERVATION.

Published in *Biol. Conserv.* (1988). **43**(3): 227-239

ABSTRACT

The status of the family Proteaceae in the Cape Floristic Kingdom is evaluated according to IUCN categories. Three species are recently extinct and, of the 121 considered rare or threatened, 33 are endangered, 29 are vulnerable and 59 are naturally rare. Fifty-three taxa are restricted to one or two populations which cover a total area of less than five km^2, making them susceptible to sudden extinction by what might otherwise be a minor disturbance. Forty-eight taxa have an estimated total count of 1000 plants or less. A system of small nature reserves is proposed to conserve such restricted rare Proteaceae.

INTRODUCTION

The Cape Floristic Kingdom is one of six such floristic kingdoms in the world (Takhtajan, 1969), yet it occupies less than 4% of the total land area of Southern Africa (Goldblatt, 1978). It is a remarkably diverse flora, comprising some 8550 species, of which 73% are endemic (Goldblatt, 1978), and covers approximately the same geographical area as the fynbos biome (Moll and Jarman, 1984a), a vegetation type defined as evergreen sclerophyllous shrublands, consisting predominantly of small- leaved species (Moll and Jarman, 1984a). The Proteaceae, with their iso-bilateral photosynthetic leaves, are a typical element restricted to the heathland communities of the fynbos biome (Moll & Jarman, 1984b).

Moll and Bossi (1984) have calculated from satellite imagery that 34% of the natural vegetation of the fynbos biome has been lost to agriculture and other human impacts since the arrival of European colonists over 300 years ago. Further, it has been determined that 19% of the Cape Flora is either naturally rare or threatened (Goldblatt, 1978; Hall *et al.*, 1984). Hall *et al.* (1984) place the total number of rare or threatened plant species in the Fynbos Biome at 1621, which alone exceeds the total British flora. The specific density (number of species per 1000km^2) of the Cape flora is 96.1 and that of the rare species 18.2. This again alone exceeds the total specific density for the British Isles, the Californian Floristic Province (an equivalent vegetation type to the fynbos), New Zealand, and Europe (Bond & Goldblatt, 1984; Goldblatt, 1978; Raven & Axelrod, 1978; Webb, 1978). The richness, in terms of high species to area ratios, is unequalled anywhere else in the world on a subcontinent scale (Gibbs Russell, 1985).

The Proteaceae, with their showy blooms, are severely threatened by wild flower picking as well as by agriculture, urban expansion, fire and invasive alien plants. A listing of threatened plants and their IUCN status, including Proteaceae, has recently been published (Hall & Veldhuis, 1985). However, no cognisance was taken of recent taxonomic revisions within the Proteaceae, nor was any recent field work carried out. The aim of this paper is to present a more up-to-date and accurate assessment of the status of the rare Cape Proteaceae and to discuss the implications of their population ecology for their conservation.

METHODS

The phytogeographical delineation used for this study is that of the Fynbos Biome as described by Moll and Bossi (1984).

The initial base for this study was provided by information held in dossiers of the rare plant data bank of the Council for Scientific and Industrial Research (CSIR), as described by Hall *et al.* (1984). Subsequently, at an *ad hoc* workshop meeting attended by Proteaceae botanists, all taxa of the Cape Proteaceae were considered as candidates for a rare plant species list. The selected taxa were then each designated a rarity status according to Red Data Book categories of the International Union for Conservation of Nature and Natural Resources (IUCN) (Synge, 1981). Although to some extent this is still subjective, it incorporates and integrates the specific knowledge, integrity, and recent field experience of a select group of recognized experts. The number of populations of each taxon, their past and present geographical range, and the estimated total number of plants for each taxon were discussed and agreed upon at the workshop. Where participants were unable to supply current data, this was then assessed from herbaria records and field checks.

RESULTS AND DISCUSSION

Present status

Eight percent of all the rare taxa of the Cape flora fall within the family Proteaceae, the remainder being scattered over more than 150 families (Bond and Goldblatt, 1984). Of the 325 taxa of Proteaceae in the Fynbos Biome (calculated from Gibbs Russell *et al.*, 1984), 306 species are endemic (Bond and Goldblatt, 1984). Within the Cape Proteaceae, three are recently extinct and 121 are rare or threatened. The categories to which these 124 taxa were ascribed by the workshop are presented in detail in the Appendix and summarized in Table 1. Of the 124 extinct, rare or threatened Proteaceae, 48% are naturally rare and 52% are threatened or recently extinct. The results of the present assessment were compared to the status of the rare Proteaceae as listed in the last CSIR rare plant data base survey in 1982: 24

Table 1: The status of rare Proteaceae of the Cape Flora in relation to the different I.U.C.N. categories (after Gibbs Russel 1985)

	Number of taxa
Proteaceae in Africa	392
Proteaceae in Cape Flora	325
Rare or threatened Proteaceae in the Cape Flora	124
Extinct Proteaceae	3
Endangered Proteaceae	33
Vulnerable Proteaceae	29
Naturally Rare Proteaceae	59
Indeterminate Proteaceae	0
Insufficiently Known Proteaceae	0

taxa have been added, 28 removed, and 34 have altered their category of rarity. The main reasons for these changes are taxonomic updating, increased knowledge of the taxa, and increased or altered threats. The above changes emphasise the need for constant updating of the data base if it is to be used as a tool for conservation management.

The critical position of the rare Cape Proteaceae is apparent when the population parameters are investigated. They exhibit a restricted geographical range, few populations and small population sizes, characteristics not as marked in the remaining more common and unthreatened members of the family. For example, 104 taxa of rare Proteaceae are restricted to five or fewer populations (Table 2), and 59 are restricted to only one or two populations. These are particularly vulnerable to relatively minor impacts. Should one or both populations be affected, extinction is likely to be a sudden and unpreventable occurrence. Such plant populations should therefore be considered highly susceptible to any impact, regardless of intensity. This is illustrated by the most recent extinction in the family, *Sorocephalus tenuifolius*, from its only recorded locality, 0.5 km^2 in the Palmiet River valley in the Hottentots Holland Mountains, due to ploughing and the planting of an apple orchard.

Sorocephalus tenuifolius is also an example of the potential threat to species with restricted distributions illustrated in Table 3. Such plant populations are extremely vulnerable to disturbance, whether anthropogenic or natural. The last known population of *Diastella buekii* was threatened by encroaching invasive alien pines prior to Directorate of Forestry intervention and control of the pines. There are 53 taxa with ranges less than 5 km^2 which are restricted to one or two populations. Of these, 28 taxa are naturally rare and so are simply local endemics. *Diastella myrtifolia* is restricted to a single population with a range of 5 km^2, but is naturally rare without any apparent threats at present.

There are 25 rare Proteaceae taxa which herbaria records show to have ranges which have decreased in the past 300 years (Appendix 1). A particularly marked example is *Protea odorata* which was widespread over the west coast forelands but now is restricted to four depauperate populations, one of which is a single plant. The natural habitat of this species has

Table 2: The number of rare or threatened Cape Proteaceae taxa in relation to the total numbers of known populations for each taxon

Number of populations	Number of taxa
1-2	59
3-5	45
6-10	15
>10	2

Table 3: The number of rare or threatened Cape Proteaceae taxa in relation to the total known geographical range

Geographical range in km^2.	Number of taxa
<,= 1	15
2 - 5	48
6 - 50	53
>50	5

largely been replaced by cultivated fields.

Many taxa are restricted in terms of their total plant count (Table 4). *Leucadendron brunioides* Meisn. var. *flumenlupinum* is naturally rare with a total plant count of 100 individuals. This is a notable exception as most of the taxa with counts of 100 plants or less are in the category endangered or extinct. For example, the endangered *Leucadendron globosum* occurs in a single population of 75 individuals. It is not known if the minimum requirements for genetic diversity are still adequate or if this plant is in effect extinct.

The reasons for wishing to conserve rare Proteaceae are numerous. Most species have horticultural potential for the export cut and dried flower industry. The free onboard value for exportation of protea blooms alone, for 1985, amounted to R7.9 million, approximately $4 million (Commissioner for Customs & Excise of the Republic of South Africa, 1985). The potential medicinal value of most of the species of Proteaceae is unknown. It has been estimated that the value of a single plant species is about $200 million (calculated in 1980 dollars) as a potential source of new drugs for human use (Farnsworth and Soejarto, 1985). Farnsworth and Soejarto (1985) anticipate that one out of every 125 flowering plant species will eventually supply a drug source. Both the above figures can be extrapolated to a world scale. Therefore of the 124 rare Proteaceae it might be expected that at least one will supply a drug source. Such a commercial value provides motivation for conservation of rare species when aesthetic and intrinsic values are inadequate.

The current economic climate has resulted in a questioning of conservation of rare species at high expense relative to the conservation of common typical species. Siegfried (1984) suggests a ranking system, with rare species which do not play an important role in the ecosystem receiving low priority for protection. Because of a lack of detailed ecological understanding within the Fynbos Biome, the biology of Proteaceae at both the community and ecosystem level are relatively unknown. Consequently, rare species cannot immediately be dismissed from consideration for conservation. However, the family appears to be particularly sensitive to disturbance and threats, which might be of value in using these plants as indicators

Table 4: The number of rare or threatened Cape Proteaceae in relation to the estimated total number of individuals for each taxon

Estimated total number of plants	Number of taxa
<500	31
600 - 1000	17
1100 - 5000	64
>5000	9

of environmental change.

Implications for management

The present small populations and restricted areas of many of the rare and threatened Proteaceae present special problems for their conservation. At present less than 16% are protected in official nature reserves C.J. Burgers, pers com.). Many others, particularly species classified as naturally rare are unprotected, yet remain relatively stable in small isolated populations.

The application of island biogeographical theory of MacArthur and Wilson (1967) to conservation management has generated much recent interest in the optimal design of nature reserves (Diamond, 1975; Simberloff and Abele, 1976; Terbough, 1976; Terbough and Winter, 1980; Boecklen, 1986). In particular, the issue of a single large reserve versus many small reserves has been raised (Simberloff & Abele, 1982). Soule and Simberloff (1986) state that recent studies have resolved the primary issue and support Gilpin and Diamond (1980) in that the equilibrium theory of island biogeography is neutral regarding single large reserves versus several small reserves. There are many examples where several small areas are seen to contain as many species or more than a single site of equal size (Gilpin and Diamond, 1980; Higgs and Usher, 1980; Simberloff and Gotelli, 1984; Zimmerman and Bierregaard, 1986). Soule and Simberloff (1986) state that the issue of the single large or several small reserves and the size range of reserves at which it breaks down is entirely dependant on the taxon under consideration (see Game and Peterken, 1984; Shaffer and Samsom, 1985).

In South Africa there is no clear cut policy regarding the design of nature reserves. Nevertheless, for protecting the Fynbos Biome adequately, Kruger (1977) has suggested a system of several reserves, the minimum size of which should not be less than 100 km^2. However, Directorate of Forestry, whose jurisdiction encompasses most large areas of natural vegetation, at present manages such areas in compartments of 5 to 15 km^2. Each compartment is managed separately, particularly with regard to controlled burning. The practical management of 5 to 15 km^2 supports a case for small nature reserves for the Cape. Results of the present study suggest that such a system would be particularly applicable to the rare Proteaceae since most of them *in toto* do not cover as much as 100km^2 (Table 4). Only five rare Proteaceae have a range in excess of 50 km^2 and 30 rare Proteaceae are restricted to a range of 1 - 2 km^2 or less. Such restricted species would be adequately protected, and buffered, in a mere 5 km^2.

Kruger(1977) quotes the commonly accepted figure of 300 individuals as a critical cutoff level required to maintain adequate genetic diversity within a plant population. It is evident that this is inapplicable to the protection of the rare Proteaceae in the Cape flora where the total count for whole taxa frequently lies well below this critical level. In addition, the family Proteaceae typically exhibit fluctuations in population size with age. For example, Boucher (1981) observed cyclic fluctuations of 10 to 1800 plants in populations of the rare *Orothamnus zeyheri*. Such cyclic fluctuations in population size make it difficult to assess the minimum population numbers required to maintain population viability. Clearly there is a need to establish minimum viable population sizes within the Cape Proteaceae, particularly for those with low total counts.

In light of evidence provided by the rare Proteaceae, it is suggested that a system of numerous reserves with areas from as small as 5 km^2 might be more appropriate for the Fynbos Biome. The emphasis should be on reserves, each representing a unique habitat, within close proximity to each other, the specific size of which would be determined by the minimum population requirements for the species in that reserve.

ACKNOWLEDGEMENTS

The author thanks E.R. Ashton, C.J. Burgers, E. Esterhuysen, A.V. Hall, C. Hilton-Taylor, C.R. McDowell, E.J. Moll, L. Nicklin, A.G. Rebelo, J.P. Rourke and M.J. Simpson, for attending and contributing to the workshop. The author thanks Professor E.J. Moll and Dr J.P.Rourke for supervision and CSIR(FRD) for financial support.

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APPENDIX

A Taxonomic Listing of all the Cape members of the Proteaceae Classified as Rare, Threatened or Extinct. Population Counts, Total Plant Counts, and Distribution Data, both Past and Present are Listed. (Taxonomy according to Rourke, 1969, 1972, 1976, 1980, 1984*a*,*b*; Levyns, 1970; Williams, 1972. Manuscript species (ms) designated by J. P. Rourke, pers. comm.).

Taxon	*Rarity status*[a]	*No. of populations*	*Total no. plants*	*Past distribution (km^2)*	*Present distribution (km^2)*
Diastella					
buekii (Gand.) Rourke	E	2	2 000	30	2
myrtifolia (Thunb.) Salisb. ex Knight	R	1	1 500	5	5
parilis Salisb. ex Knight	V	1	2 000	30	1
proteoides (L.) Druce	V	5	5 000	30	30
Leucadendron					
argenteum (L.) R.Br.	R	8	10 000	20	20
bonum Williams	E	1	250	0·5	0·5
brunioides Meisn. var. *flumenlupinum* Williams	R	1	100	0·5	0·5
caulens Williams	R	1	1 000	3	3
chamelaea (Lam.) Williams	E	8	10 000	50	50
concavum Williams	R	2	400	2	2
coriaceum, Phillips & Hutch.	E	2	600	15	15
corymbosum Berg.	V	7	5 000	30	30
cryptocephalum Guthrie	E	3	1 250	100	100
daphnoides (Thunb.) Meisn.	V	5	5 000	50	50
diemontianum Williams	R	2	200	5	5
discolor Phillips & Hutch.	E	5	100	30	1
elimense Phillips					
subsp. *elimense*	V	10	2 000	10	10
subsp. *salteri* Williams	E	2	1 500	10	10
subsp. *vyeboomense* Williams	E	1	20	5	1
flexuosum Williams	E	1	500	5	2
floridum R.Br.	E	2	500	4	4
galpini Phillips & Hutch.	V	1	10 000	10	10
globosum (Kennedy ex Andrews) Williams	E	1	75	5	0·5
laxum Williams	E	25	5 000	10	10
levisanus (L.) Bergius	E	3	5 000	50	20
macowenii Phillips	E	2	5 000	3	3
nervosum Phillips & Hutch.	R	2	5 000	6	6
platyspermum R.Br.	V	5	10 000	30	30
radiatum Phillips & Hutch.	R	3	500	50	50
roodii Phillips	R	1	1 000	3	3
sericeum (Thunb.) R.Br.	V	4	2 500	5	5
singulare Williams	R	4	300	4	4
sorocephalodes Phillips & Hutch.	R	6	2 000	15	15
spirale (Salisb. ex Knight) Williams	X	1	1	0·5	0·5
stelligerum Williams	E	3	1 000	4	4
strobilinum (L.) Druce	R	2	5 000	20	20
thymifolium (Salisb. ex Knight) Williams	V	8	700	30	30
tradouwense Williams	R	2	2 500	2	2
verticillatum (Thunb.) Meisn.	E	5	500	5	5
Leucospermum					
arenarium Rycr.	R	1	200	3	3
cordatum Phillips	R	1	2 500	1	1
formosum (Andrews) Sweet	V	3	750	250	250
fulgens Rourke	E	1	300	5	1
grandiflorum (Salisb.) R.Br.	V	3	1 500	15	15
gueinzii Meisn.	R	3	3 000	20	20
heterophyllum (Thunb.) Rourke	V	1	2 800	10	5
parile (Salisb. ex Knight) Sweet	V	5	5 000	20	20
pedunculatum Klotzsch	R	2	1 000	10	10
praecox Rourke	V	4	10 000	10	10
profugum Rourke	R	2	250	1	1
tomentosum (Thunb.) R.Br.	V	4	2 000	55	26
Mimetes					
arboreus Rourke	R	3	2 000	5	5
argenteus Salisb. ex Knight	R	5	4 000	20	20
capitulatus R.Br.	R	3	1 500	15	15
hirtus (L.) Salisb. ex Knight	V	10	30 000	150	150
hottentoticus Phillips & Hutch.	R	3	1 500	3	3
palustris Salisb. ex Knight	R	5	2 500	5	5
splendidus Salisb. ex Knight	R	8	700	300	300
stokoei Phillips & Hutch.	X	1	1	1	1

(continued)

APPENDIX—*contd.*

Taxon	*Rarity status**	*No. of populations*	*Total no. plants*	*Past distribution (km^2)*	*Present distribution (km^2)*
Orothamnus					
zeyheri Pappe ex Hook. f.	R	13	3 000	15	15
Paranomus					
abrotanifolius Salisb. ex Knight	V	10	5 000	20	20
adiantifolius Salisb. ex Knight	R	4	5 000	10	10
capitatus (R. Br.) Kuntze	R	3	3 000	10	10
centaureoides Levyns	R	1	2 000	3	3
longicaulis Salisb. ex Knight	R	4	4 000	30	30
reflexus (Phillips & Hutch.) N.E.Br.	R	4	200	30	30
roodebergensis (Compton) Levyns	R	2	5 000	5	5
spicatus (Bergius) Kuntze	R	3	800	10	10
Protea					
angustata R.Br.	V	5	1 000	55	30
aurea (Burm. f.) Rourke subsp. *potbergensis* Rourke	R	1	1 000	1	1
cryophila Bolus	R	6	5 000	3	3
decurrens Phillips	V	6	5 000	50	30
holosericea (Salisb. ex Knight) Rourke	R	1	2 500	5	5
inopina Rourke	R	3	1 000	7	7
lanceolata Meyer ex Meisn.	V	5	10 000	150	150
mucronifolia Salisb.	V	1	3 000	20	3
namaquana ms	R	1	200	1	1
odorata Thunb.	E	4	1 000	20	20
pudens Rourke	V	1	4 000	30	3
restionifolia (Salisb. ex Knight) Rycr.	V	5	4 000	15	15
scorzonerifolia (Salisb. ex Knight) Rycr.	V	8	4 000	25	25
Serruria					
aemula Salisb. ex Knight	E	3	1 000	20	20
amoena ms	R	3	2 000	10	10
brownii Meisn.	E	5	4 000	50	30
candicans R.Br.	R	3	20 000	10	10
collina Salisb. ex Knight	V	4	500	10	10
confragosa Rourke	R	3	500	5	5
cyanoides (L.) R.Br.	V	3	3 000	20	5
decumbens (Thunb.) R.Br.	R	1	1 500	2	2
flava Meisn.	R	1	3 000	2	2
florida (Thunb.) Salisb. ex Knight	V	1	1 000	5	5
furcellata R.Br.	E	2	250	75	50
glabra ms	R	1	2 000	5	5
hirsuta R.Br.	R	1	1 500	5	5
incrassata Meisn.	V	5	1 000	20	20
kraussii Meisn.	R	3	2 000	7	7
leipoldtii Phillips & Hutch.	R	1	2 000	5	5
linearis Salisb. ex Knight	E	4	3 000	30	5
meisneriana Schltr.	R	1	5 000	2	2
millefolia Salisb. ex Knight	V	10	5 000	50	20
patersonia ms	R	1	1 000	5	5
pinnata R.Br.	R	10	7 000	30	30
roxburghii R.Br.	E	2	3 000	30	5
trilopha Salisb. ex Knight	E	5	500	30	30
triternata (Thunb.) R.Br.	E	1	200	30	5
williamsii Rourke	R	2	1 500	5	5
Sorocephalus					
alopercurus Rourke	R	1	400	1	1
capitatus Rourke	R	2	3 000	20	20
crassifolius Hutch.	E	1	25	1	1
imbricatus (Thunb.) R.Br.	E	1	2	5	0·1
palustris Rourke	E	2	20	1	1
pinifolius (Salisb. ex Knight) Rourke	E	1	500	2	2
scabridus Meisn.	E	1	200	7	2
tenuifolius R.Br.	X	1	1	2	0·5
teretifolius (Meisn.) Phillips	R	3	1 500	5	5
Spatalla					
argentea Rourke	R	1	500	2	2
colorata Meisn.	R	3	3 000	50	50
ericoides Phillips	E	1	500	30	2
nubicola Rourke	R	2	5 000	5	5
prolifera (Thunb.) Salisb. ex Knight	E	2	3 000	10	10
propinqua R.Br.	R	10	2 000	30	30
salsoloides (R.Br.) Rourke	R	2	1 500	3	3
tulbaghensis (Phillips) Rourke	E	1	100	3	3
Vexatorella					
latibrosa Rourke	R	2	5 000	2	2

* X, extinct; E, endangered; R, rare; V, vulnerable.

CHAPTER 2

THE DISTRIBUTION OF THREATENED CAPE PROTEACEAE, SOUTH AFRICA

ABSTRACT: The distribution of the rare Cape Proteaceae taxa was examined and compared to that for all the Cape Proteaceae. Analysis shows that 3 % of the 150 km^2 grid squares containing Cape Proteaceae, have significantly more rares than expected. These grid squares lie in two distinct areas; Cape Town and the coastal forelands to the north as far as Darling, and the Elandsberg mountains. An examination of the anthropogenically rare taxa adds the Elim flats to these areas. All three areas are recommended for further conservation input. The distribution of the naturally rare taxa reflects areas known to be particularly rich in species, which are regarded as centres of endemism.

Introduction

The flora of the South Western Cape Province, South Africa, is both unique and diverse, so much so that it is ascribed the status of Floral Kingdom (Takhtajan, 1969). In area it covers some 90000 km^2 and is approximated in distribution by the fynbos biome a mapped by Moll & Bossi (1984a). The vegetation is a sclerophyllous shrubland represented by some 8 504 species of seed plants (Bond and Goldblatt, 1984) with a marked degree of endemism.

The family Proteaceae is a conspicuous and characteristic dominant of the Cape Flora and comprises some 320 species, of which 306 are endemic. Taxonomically, it is one of the best known indigenous families with herbaria records dating from the earliest European settlers over 200 years ago.

The Cape Flora is shrinking rapidly in terms of remaining natural vegetation. Moll & Bossi (1984b) estimate that 34% has already been lost. The effect of this loss is reflected in the high incidence of rare plant taxa which Hall *et al.* (1984) estimate to be at least 1 600. More specifically, earlier work in this study has revealed that 124 taxa, or 8% of the rare plants, are within the family Proteaceae (see chapter 1). These can divided broadly into two groups, 59 being naturally rare under no known threat at present and 65 being catergorised as vulnerable, endangered or recently extinct (see Chapter 1).

Greyling & Huntley (1984) estimated that there is approximately 12% of the existing natural vegetation of the fynbos biome conserved at present. This included forestry areas on mountain slopes, some of which are no longer natural, and private nature reserves whose future is at best tenuous. This percentage is reduced to 8% when the whole fynbos biome of 90 000 km^2 is considered. In addition, it is noted that the areas conserved are not necessarily representative of the relative areas occupied by the different vegetation types described by Moll *et al.* (1984). For example, only 1.4% of lowland vegetation types are protected in reserves (Greyling & Huntley, 1984). Jarman (1986) attempted to identify threatened habitats in lowland fynbos and to rank remaining natural areas based on a set of ecological characteristics. The dominant factor selected was vegetation type. This was weighted heavily in favour of the scarcer habitat types, such as Renosterveld. The results therefore ranked sites within such vegetation types above all others.

The specific aim of this paper is to examine the distribution of the Cape Proteaceae, particularly those categorized as naturally rare, vulnerable or endangered, and to identify areas with exceptionally high concentrations of rare taxa for potential conservation consideration. It is hoped that the assessment of the distribution of the rare Proteaceae would provide an independent, accurate and unbiased assessment for identifying priority concentrations of rare plants using the family Proteaceae as a pilot study.

Study area and Methods

The study area included the whole of the fynbos biome as described by Moll and Bossi (1984a). The distribution range of each taxa of Cape Proteaceae was recorded onto a grid of 857 1/16 ° squares using a modified grid reference system of Edwards & Leistner (1971) such that each grid square measured 12 x 12 km (144 km^2). The distributions of the different genera were mapped with the rare taxa in each genus overlaying this distribution. Areas covered by the rare taxa were calculated.

The distributions of the naturally rare and the anthropogenically rare taxa (vulnerable, endangered and extinct taxa as determined in Chapter 1) were plotted separately and together. For each set of distribution points plotted, the number of taxa per grid square was recorded to allow quantitative assessment of concentrations. All three distributions (naturally rare, threatened, and both together) were plotted on the total distribution of the Cape Proteaceae, using linear regression analysis (Zar, 1974). This allowed an investigation of the relationship between the total number of Proteaceae taxa and the number of rare taxa per 12 x 12km square. Grid squares found to lie outside the upper 95 % prediction limit were then interpreted as having more rare taxa than could reasonably be expected. Grid squares, of which there very few, found to lie below the lower 95% prediction limit were not dealt with in this paper.

Results and Discussion

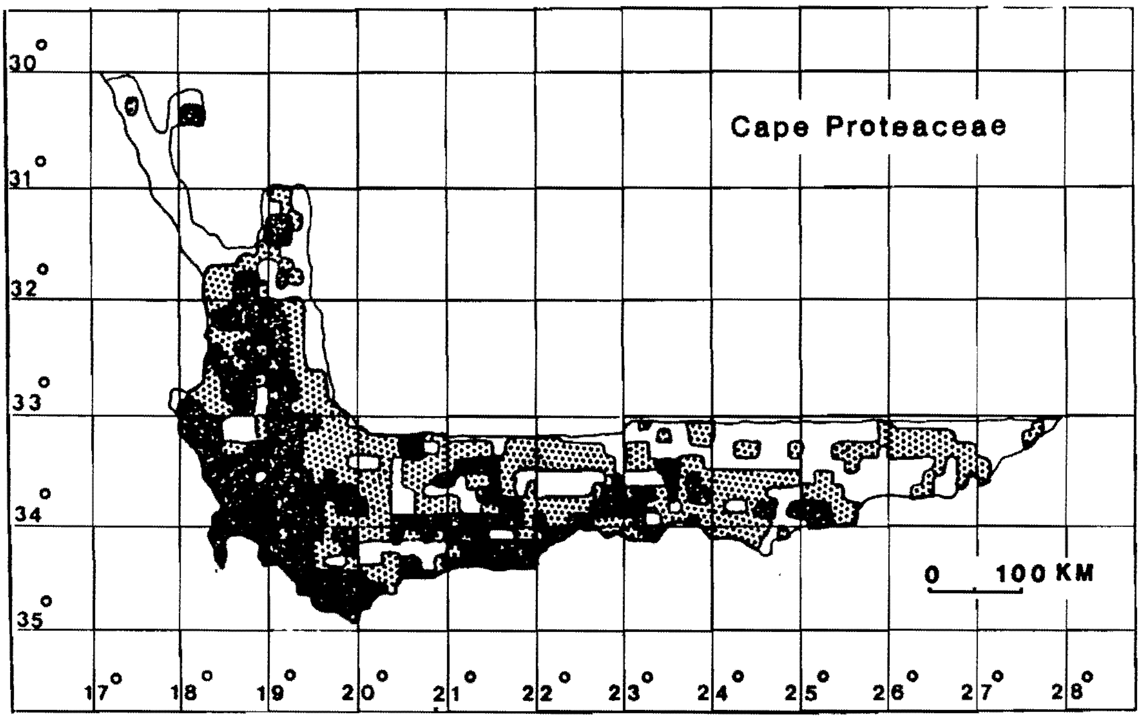
The Cape Proteaceae occupy 560 grid squares, 65 % of the total area of the fynbos biome (Fig. 1). Rare taxa occupy a total of 263 grid squares, 47 % of the area occupied by Cape Proteaceae. High concentrations of taxa, measured as numbers of taxa per grid, lie in the Hottentots Holland and Kogelberg mountains. Oliver *et al.* (1983) found a similar node with their coarse grid study. In grid square 3419 AAd, the highest concentration with 58 taxa, is found (Fig. 2). This grid lies over the Houwhoek mountains, east of the Kogelberg. Weimark (1941) divided the Cape flora into "endem centres", one of which, the Hottentots Holland subcentre, is characterised by high concentrations of many different Cape endemics. The limits of this subcentre are directly equivalent to the high concentration of Cape Proteaceae. Levyns (1964) observed that many Cape genera were characterised by a maximum concentration of taxa in the Caledon Division, into which the Kogelberg mountains fall. However in this area the number of rare Proteaceae taxa falls well within the expected limits (Fig. 3).

Distribution of the genera

A total of 13 genera of Proteaceae are indigenous to the fynbos biome, of which two, *Aulax* and *Brabejum*, have no rare taxa and are not considered further. The distributions of the 11 genera containing rare taxa are mapped in Fig. 1.

Serruria, *Protea*, *Leucadendron* and *Leucospermum* are ubiquitous throughout the fynbos biome although *Serruria* is restricted to the west of longitude 22°E. The representative areas covered by the different genera shows that only *Protea*, *Leucadendron*, and *Leucospermum* cover more than 60 % of the distribution of the Cape Proteaceae (Table 1). This is to be expected as these genera are numerically strong as well being characterised by a ubiquitous distribution. The distribution of rare taxa as a percentage of the area occupied by

FIG.1. The total distribution of Cape Proteaceae (dotted and shaded) and all the rare taxa (shaded). The total distribution range of 11 genera of Cape Proteaceae (dotted and shaded) and the distribution of their rare taxa (shaded).


Cape Proteaceae
30°
31°
32°
33°
34°
35°
0 100 KM
17°
18°
19°
20°
21°
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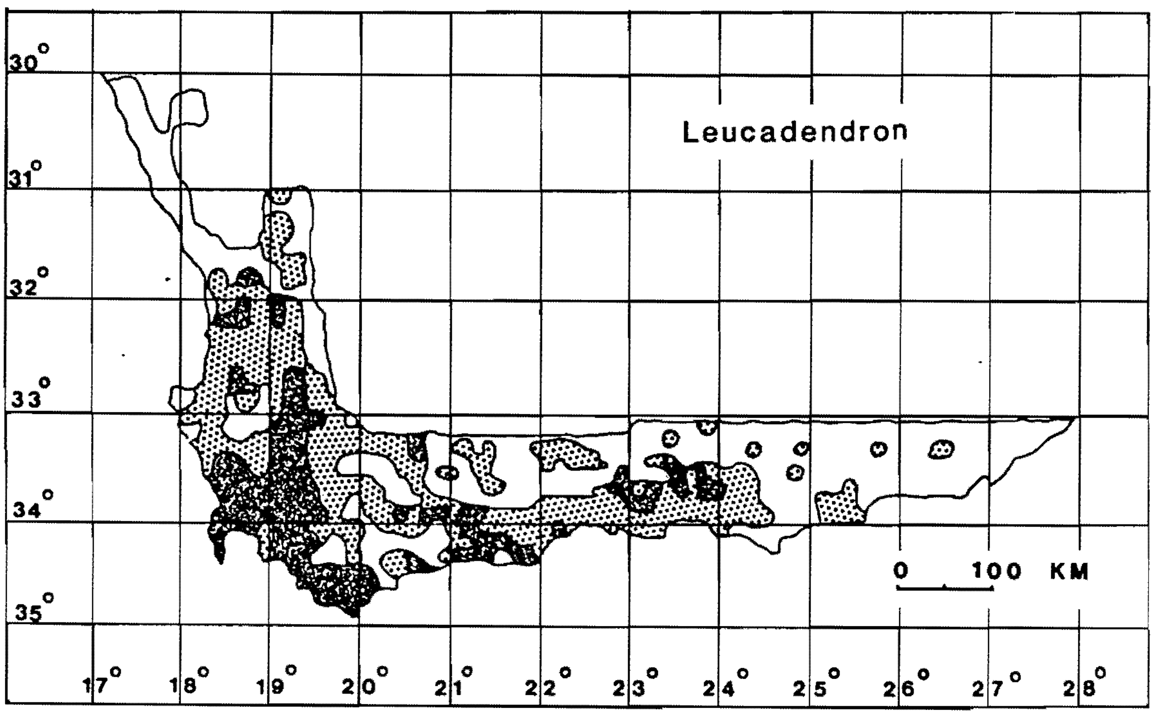
23°
24°
25°
26°
27°
28°


Leucadendron
30°
31°
32°
33°
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0 100 KM
17°
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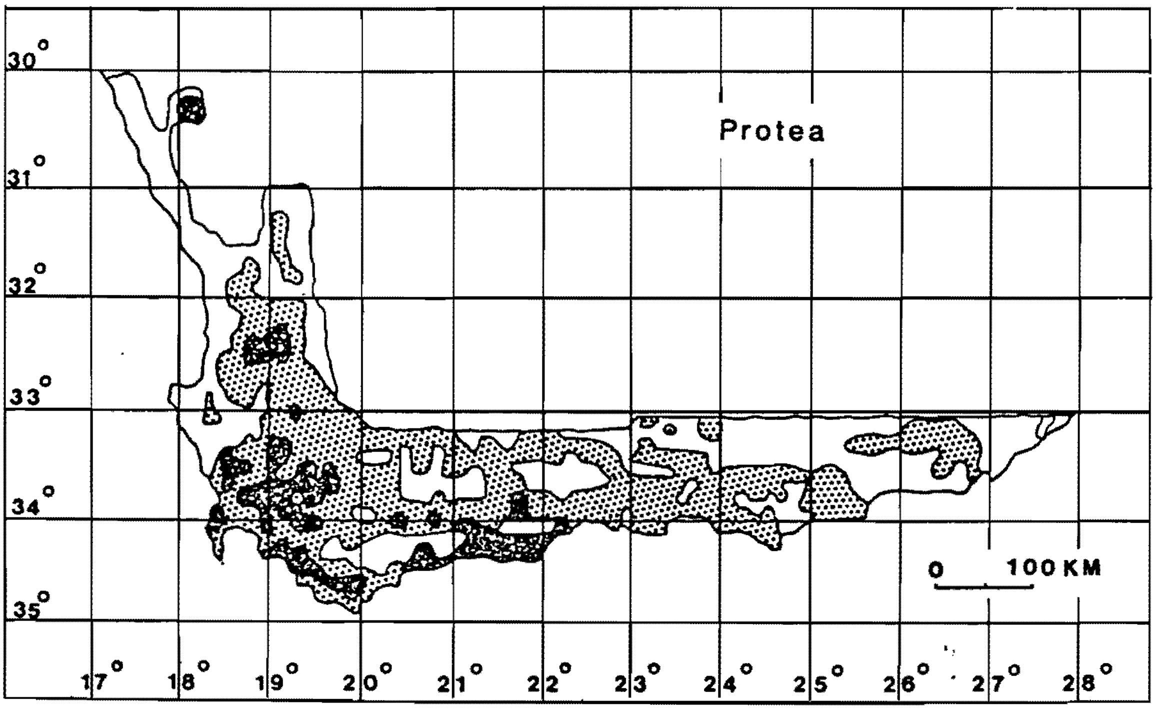
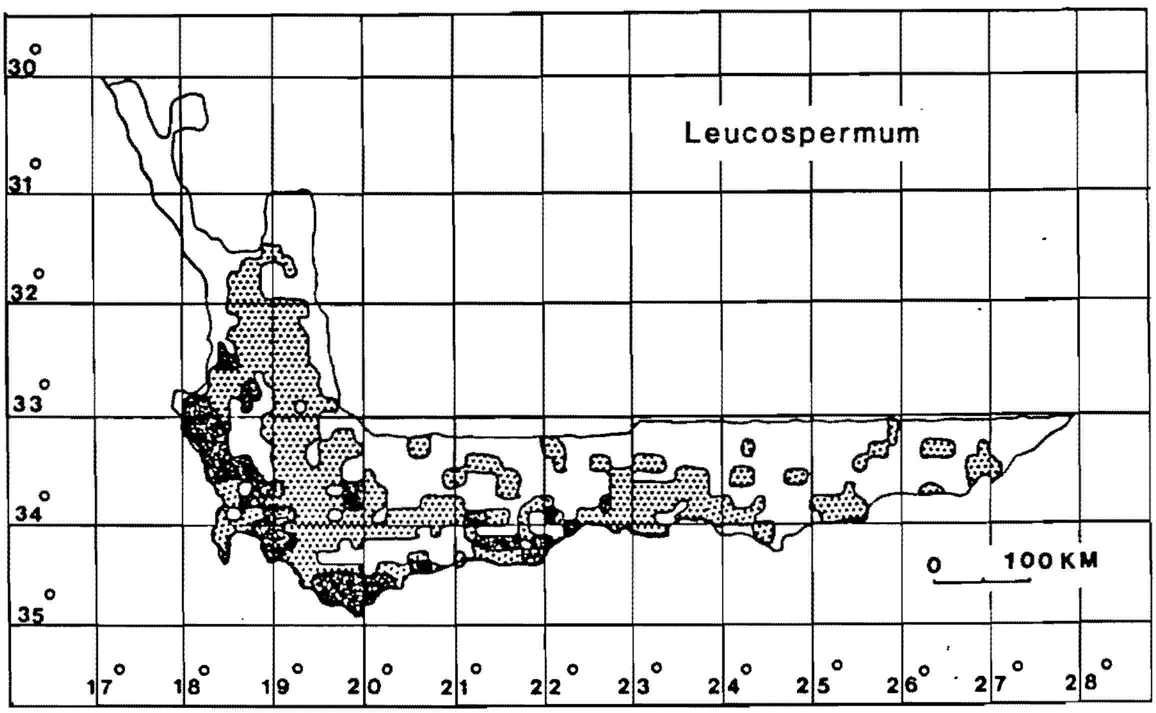
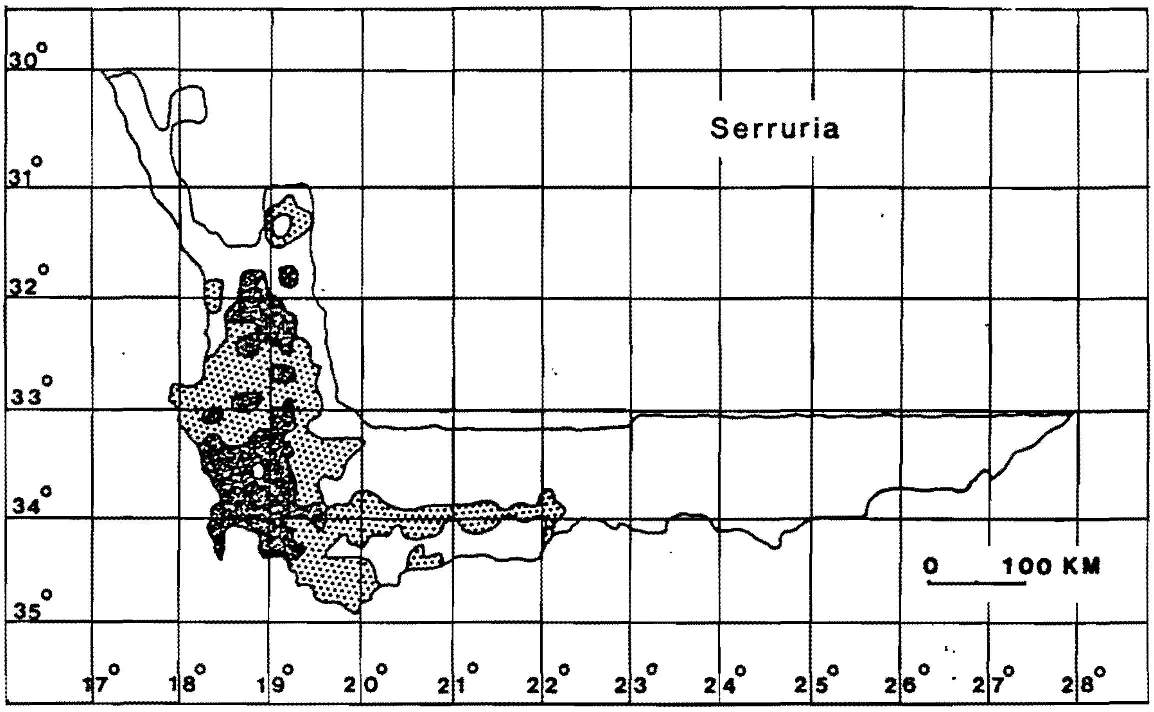


30°
31°
32°
33°
34°
35°
Protea
0 100 KM
17° 18° 19° 20° 21° 22° 23° 24° 25° 26° 27° 28°



30°
31°
32°
33°
34°
35°
Leucospermum
0 100 KM
17° 18° 19° 20° 21° 22° 23° 24° 25° 26° 27° 28°



Serruria
0 100 KM
30°
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32°
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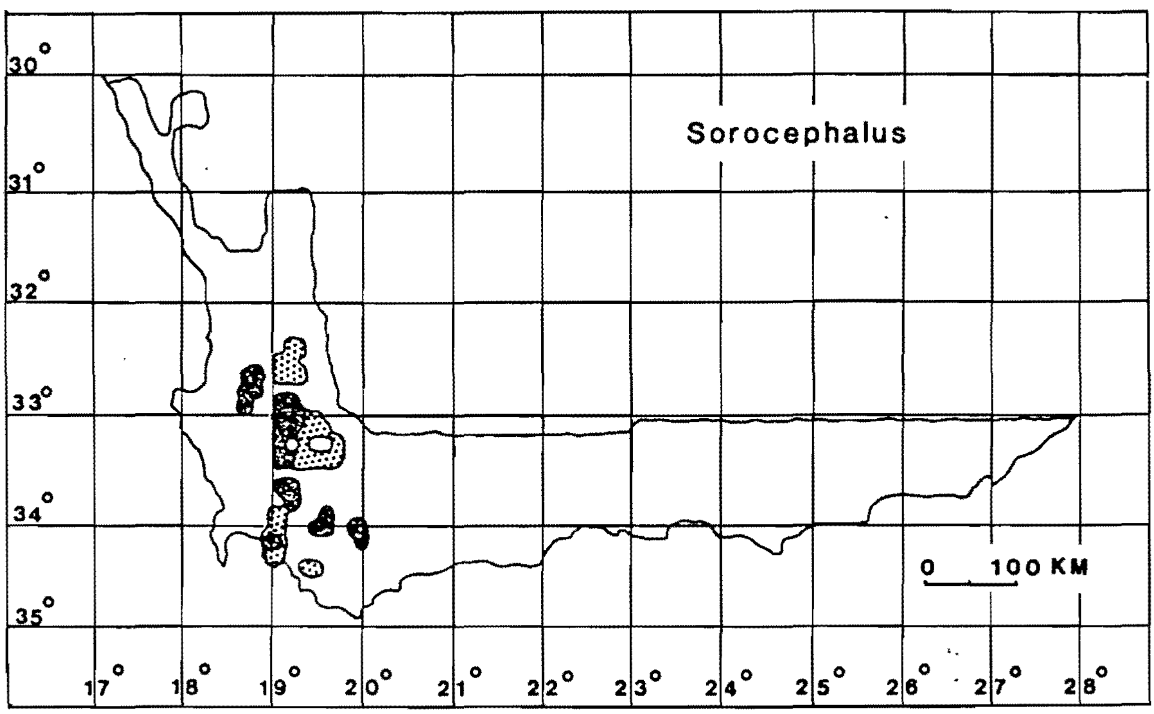
17° 18° 19° 20° 21° 22° 23° 24° 25° 26° 27° 28°



Sorocephalus
0 100 KM
30°
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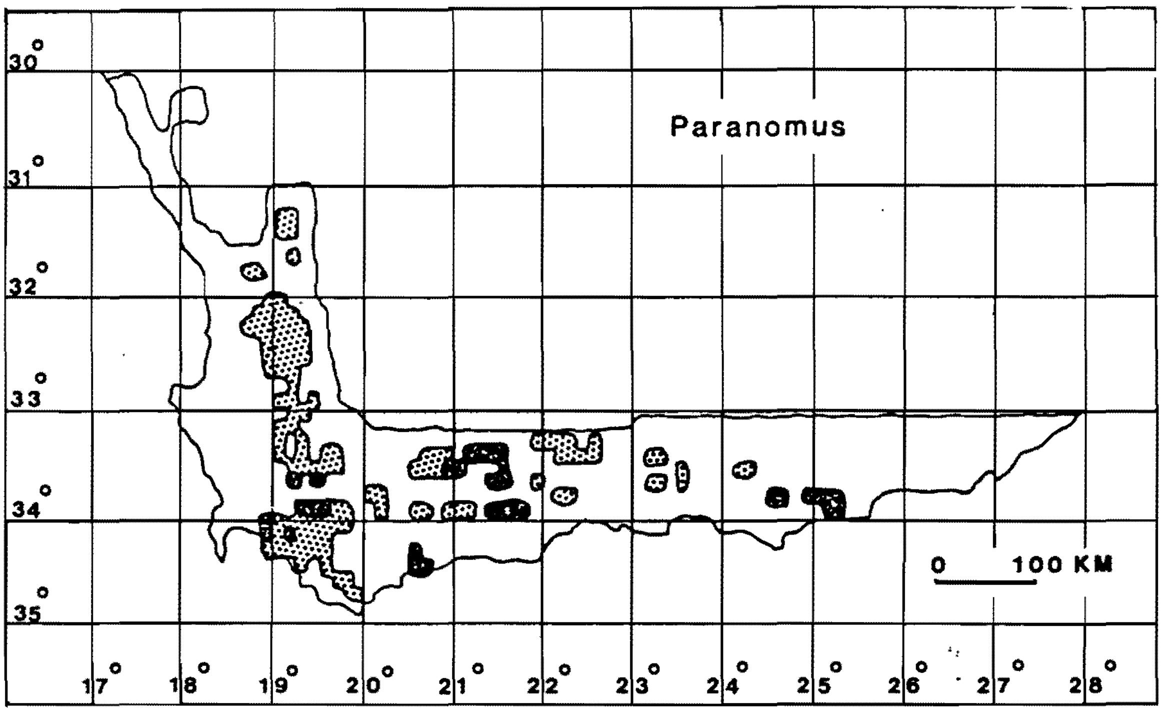
33°
34°
35°
17° 18° 19° 20° 21° 22° 23° 24° 25° 26° 27° 28°


Paranomus
0 100 KM
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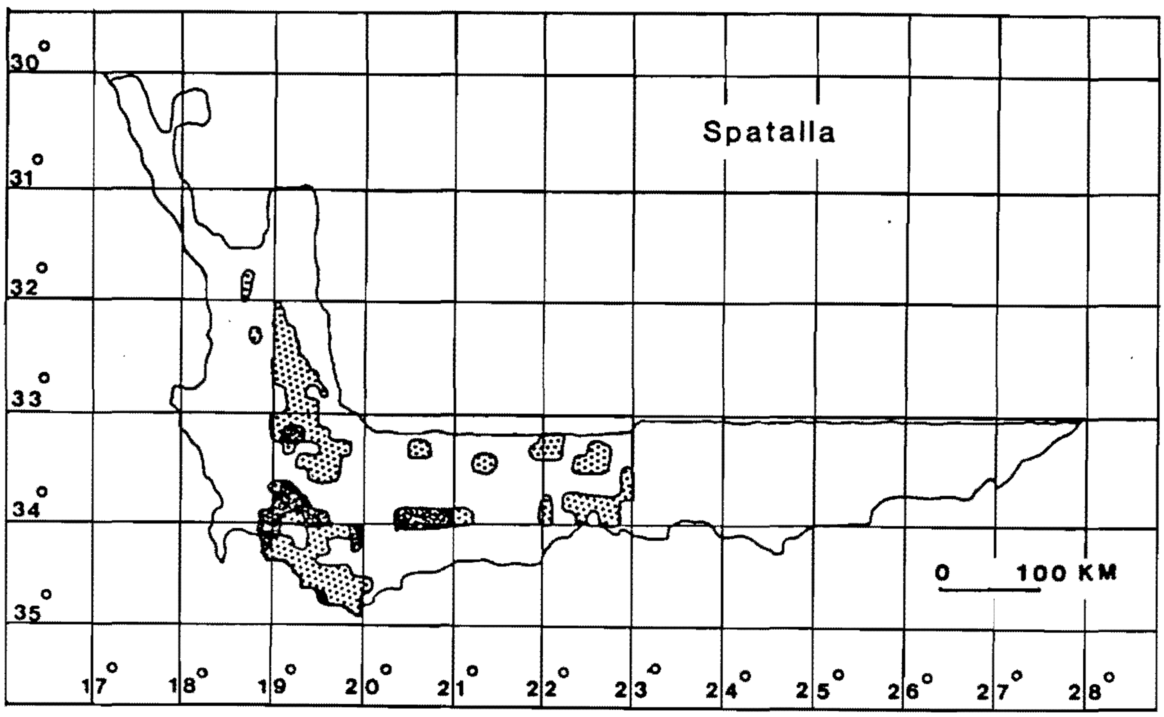
35°
17° 18° 19° 20° 21° 22° 23° 24° 25° 26° 27° 28°


Spatalla
0 100 KM
30°
31°
32°
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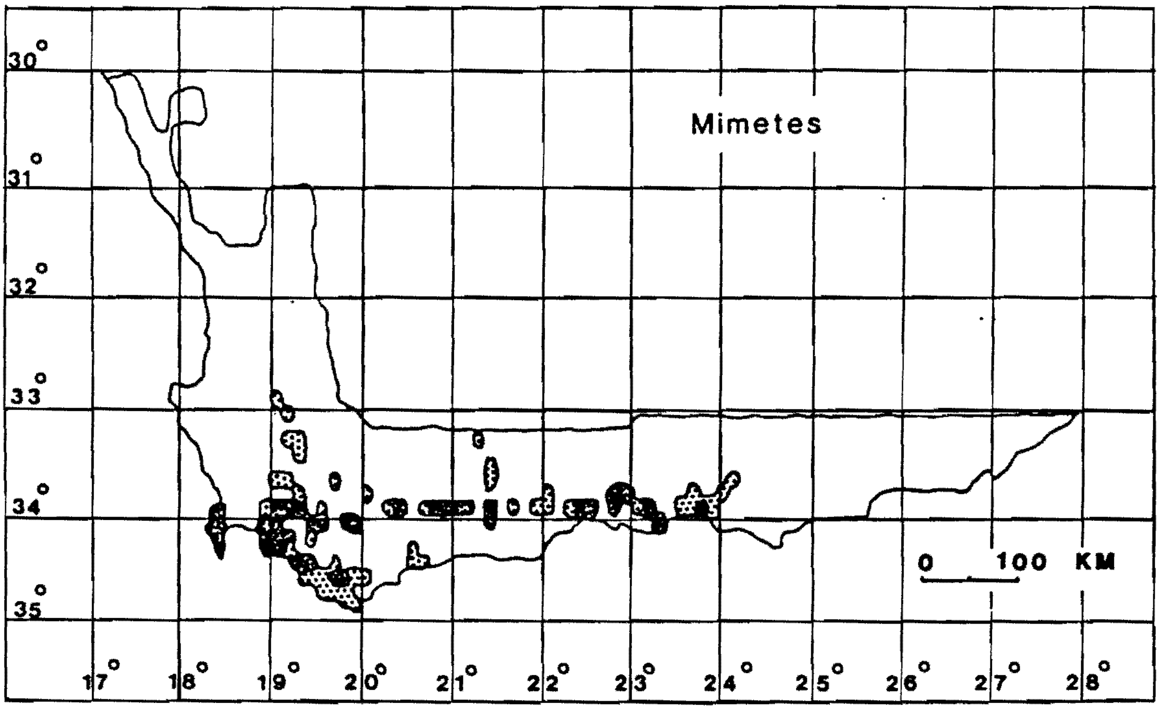
34°
35°
17° 18° 19° 20° 21° 22° 23° 24° 25° 26° 27° 28°


Mimetes
0 100 KM
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32°
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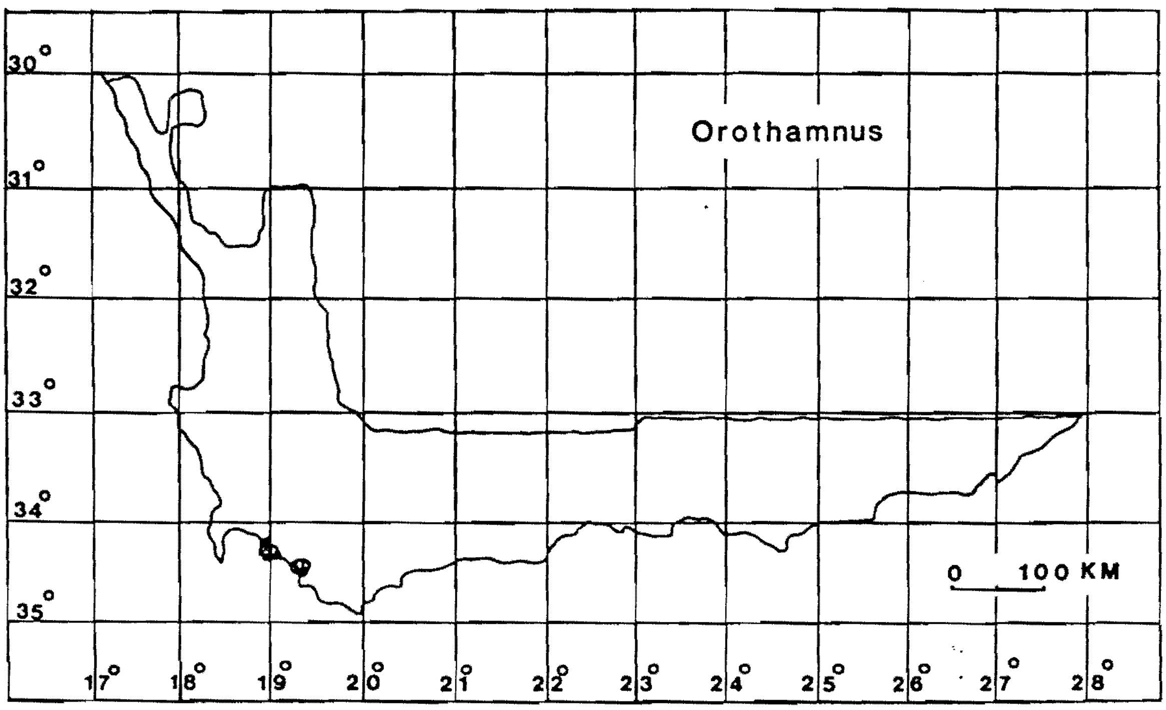
Orothamnus
0 100 KM
30°
31°
32°
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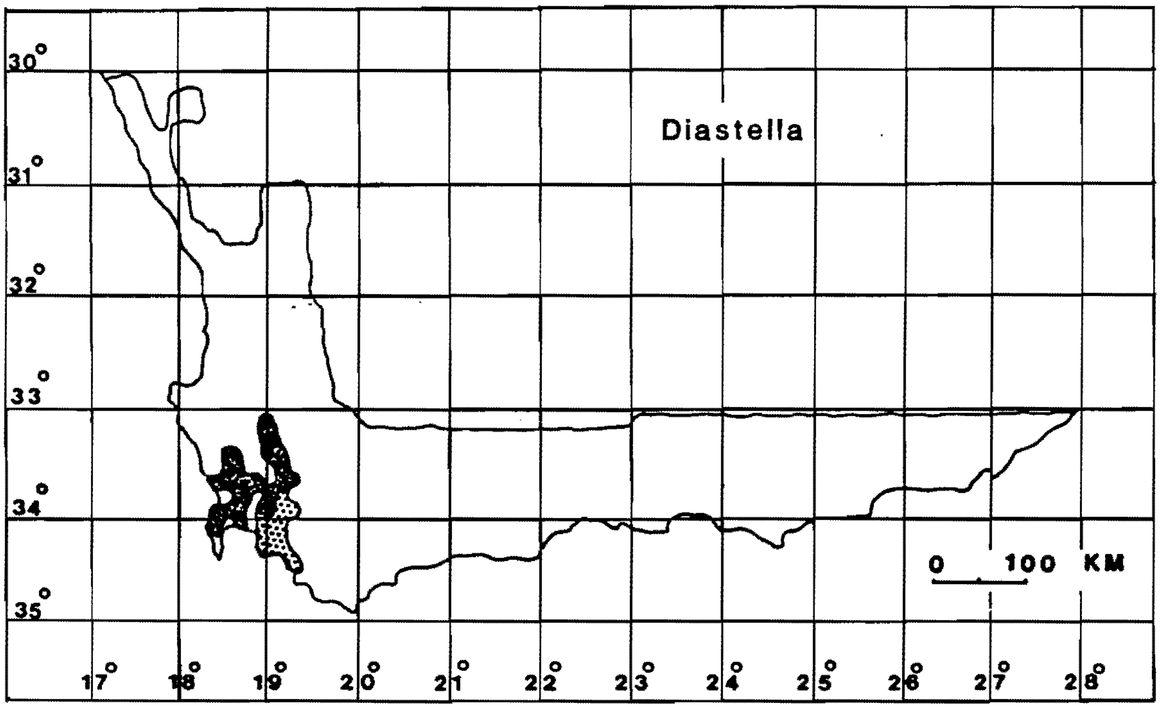
Diastella
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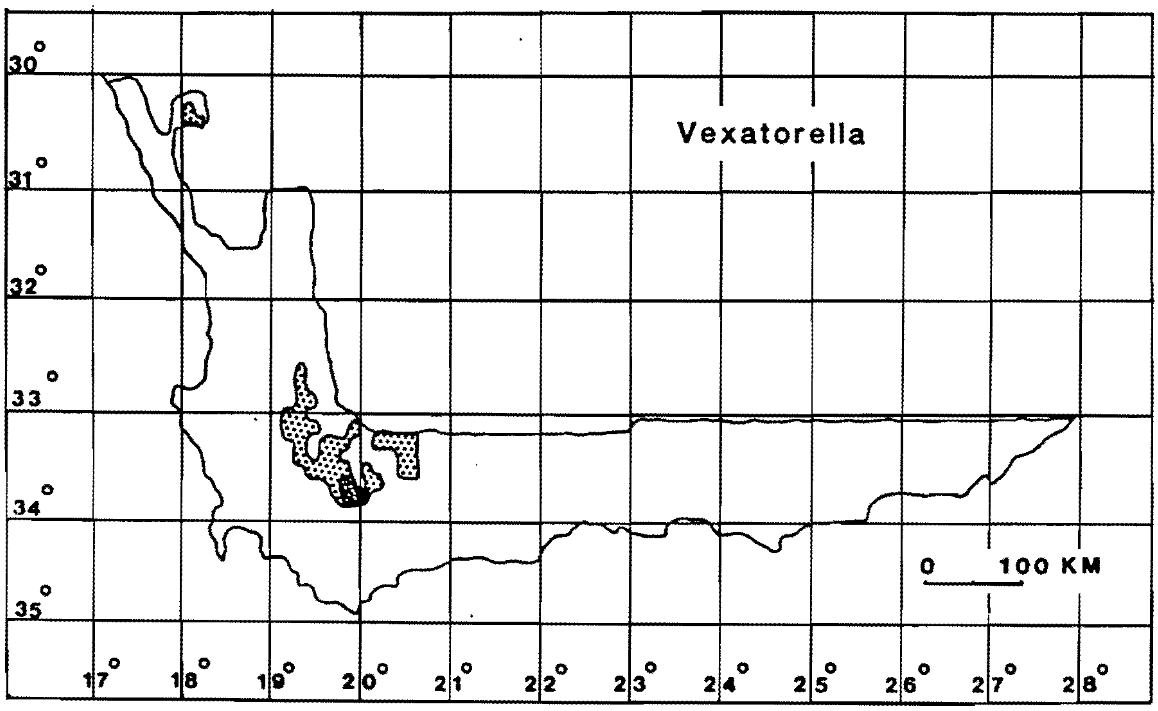
0 100 KM


Vexatorella
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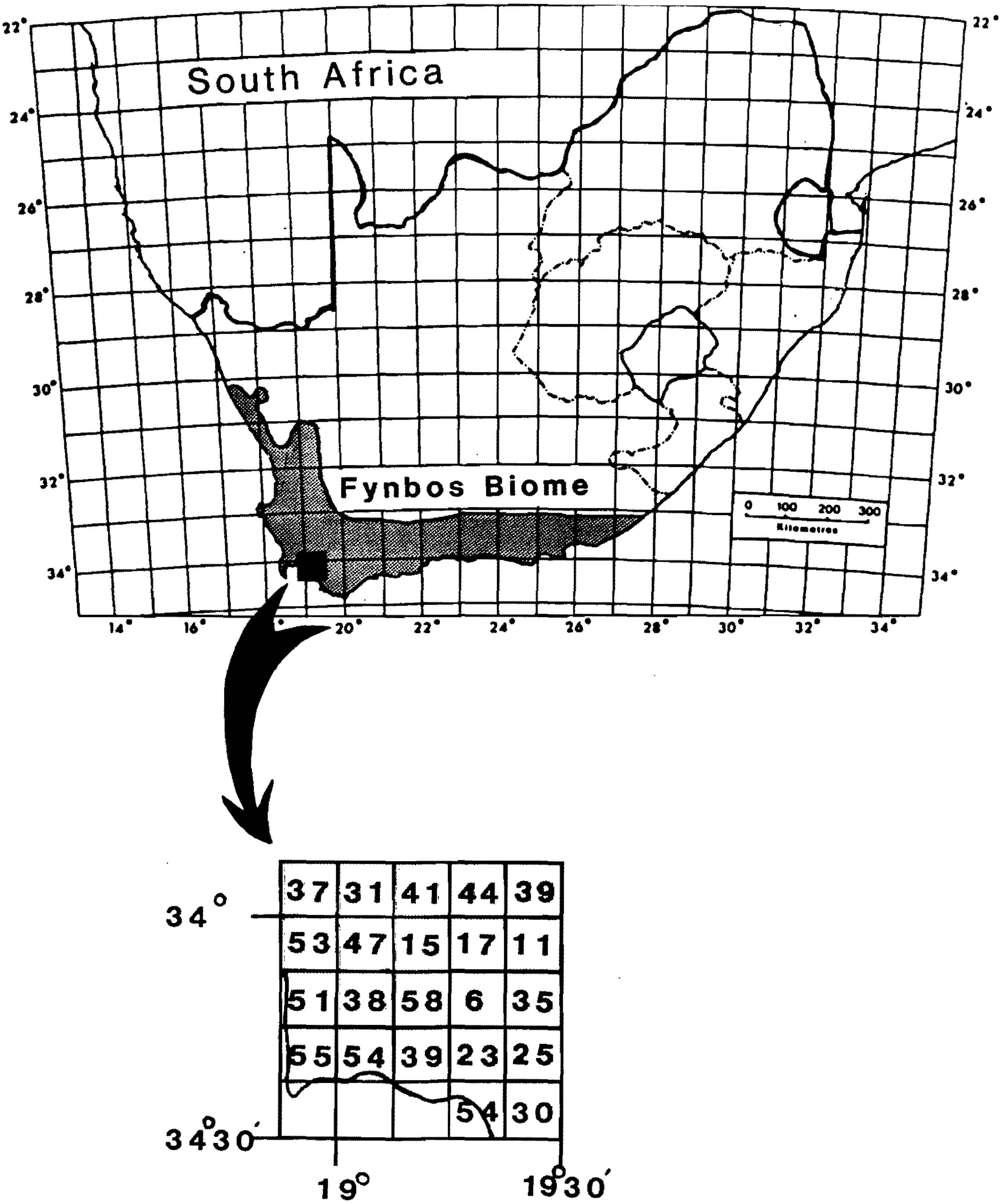
25°
26°
27°
28°
0 100 KM

FIG.2. The South Western portion of the fynbos biome showing the node and centre of the distribution of Cape Proteaceae, with a plot of the number of taxa per grid square.



South Africa
Fynbos Biome
0 100 200 300
Kilometres
22°
24°
26°
28°
30°
32°
34°
14°
16°
20°
22°
24°
26°
28°
30°
32°
34°
37 31 41 44 39
53 47 15 17 11
51 38 58 6 35
55 54 39 23 25
54 30
34°
34°30′
19°
19°30′

FIG.3. (a) The relationship between rare Proteaceae taxa and the total number of Cape Proteaceae taxa per grid. $y = 0.45 + 0.15x$, $t_b = 16.12$, $P < 0.001$, $r = 0.78$.

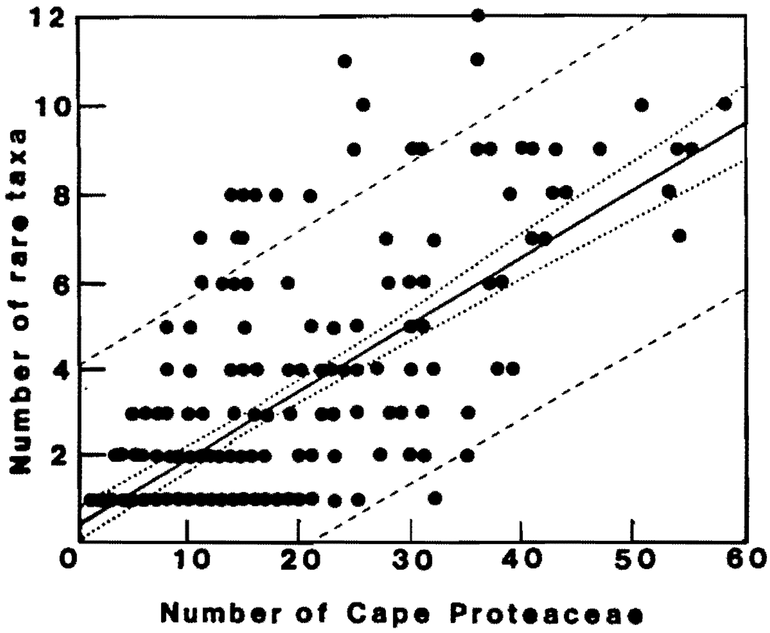
(b) The relationship between anthropogenically rare Proteaceae taxa (Vulnerable, endangered or extinct) and the total number of Cape Proteaceae taxa per grid square. $y = 0.6 + 0.08x$, $t_b = 8.39$,

$P < 0.001$, $r = 0.46$

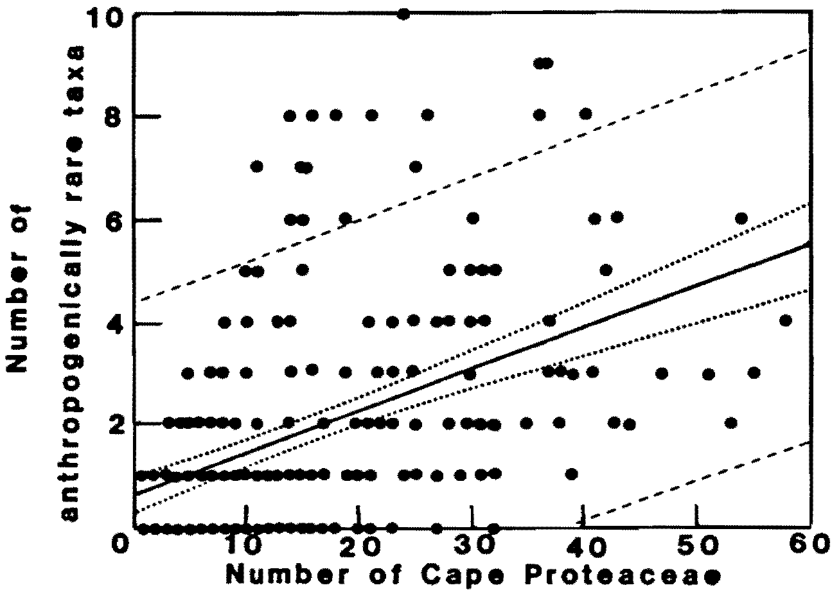
(c) The relationship between naturally rare Proteaceae taxa and the total number of Cape Proteaceae taxa per grid square.

$y = - 0.15 + 0.07x$, $t_b = 13.67$, $P < 0.001$, $r = 0.65$.

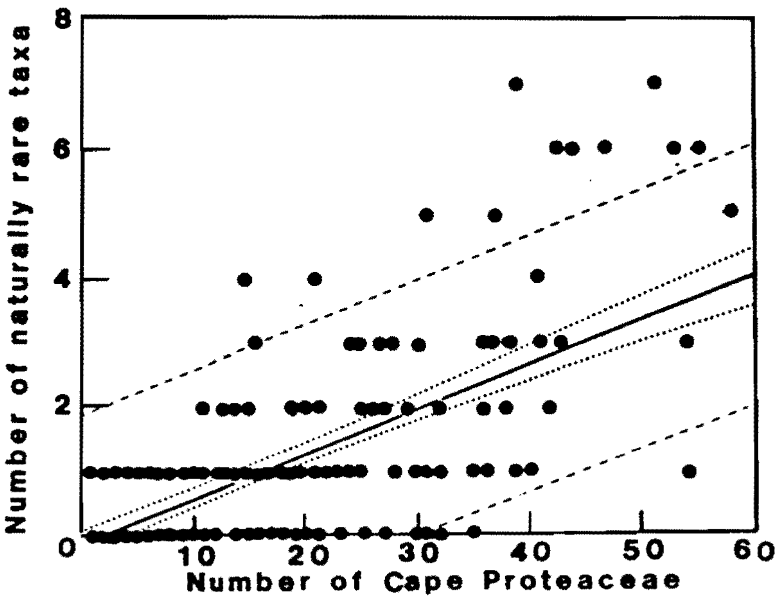
The dotted lines represent the 95 % confidence levels and the dashed lines represent the 95 % prediction limits.


Number of rare taxa
Number of Cape Proteaceae
0
10
20
30
40
50
60
2
4
6
8
10
12

(a)


Number of
anthropogenically rare taxa
Number of Cape Proteaceae
0
10
20
30
40
50
60
2
4
6
8
10

(b)


Number of naturally rare taxa
Number of Cape Proteaceae
0
10
20
30
40
50
60
2
4
6
8

(c)

TABLE 1: A measure in grid square units of the areas occupied by each genus and by the rares in each genus. 1 = the number of grid squares occupied per genus. 2 = the number of grid squares occupied by rare taxa per genus. 3 = the area occupied by rare taxa as a percentage of grids occupied by rare taxa out of the total number of grids occupied by the genus. 4 = The area occupied by the genera as a percentage of the total number of grid occupied by the Cape Proteaceae (560 squares). 5 = the area occupied by the rare taxa per genus as a percentage of the total number of grid squares occupied by the total distribution of rare taxa of Cape Proteaceae (263 squares).

Genus	1	2	3	4	5
Diastella	41	26	63	7	10
Leucadendron	418	139	33	75	53
Leucospermum	360	74	21	64	28
Mimetes	80	36	45	14	14
Orothamnus	4	4	100	1	2
Paranomus	139	35	25	25	13
Protea	461	93	20	82	35
Serruria	222	93	42	40	35
Sorocephalus	51	26	51	10	10
Spatalla	120	23	19	21	9
Vexatorella	39	3	8	7	1

rare Proteaceae (column 5, Table 1), shows the three large ubiquitous genera dominating the distribution. *Serruria* with its rares covering 35 % of the total rare taxa distribution, is included. This might be accounted for by the rare *Serruria* taxa largely being found on lowland plains suitable for agriculture, such as the west coast forelands. Levyns (1970) has suggested that this genus is undergoing active speciation on the lowlands yet the analysis of its present distribution shows the highest concentration of taxa to be in the Riviersondereind Mountains.

Rare *Protea* taxa do not extend east of longitude 22° 8'E and rare *Leucodendron* taxa are concentrated in two distinct nodes, the west coast north of Cape Town and the Hottentot Holland mountain area. Rare *Leucospermum* taxa are typically local coastal endemics, both on the west and the south coast plains.

Vexatorella is the most recently discovered genus (Rourke, 1984b) and is restricted in distribution to dry mountain tops. Rourke (1984b) suggests that this genus is a relictual remnant related to *Leucadendron*.

In *Spatalla*, *Sorocephalus* and *Paranomus*, there is a distinctly high altitude distribution along the mountain chains with the Cape Peninsula being a notable exception in all three cases. *Sorocephalus* is not found east of 20°E whereas *Paranomus* is extremely widespread for such a small genus. Levyns (1970) has suggested that this is indicative of a previously more widespread distribution.

Mimetes is largely restricted to mountainous regions although in the past it was certainly more widespread (Rourke, 1984a). Although the Kogelberg Mountains contain half the known species, Rourke (1984a) warns that this area cannot be assumed to be the centre of speciation.

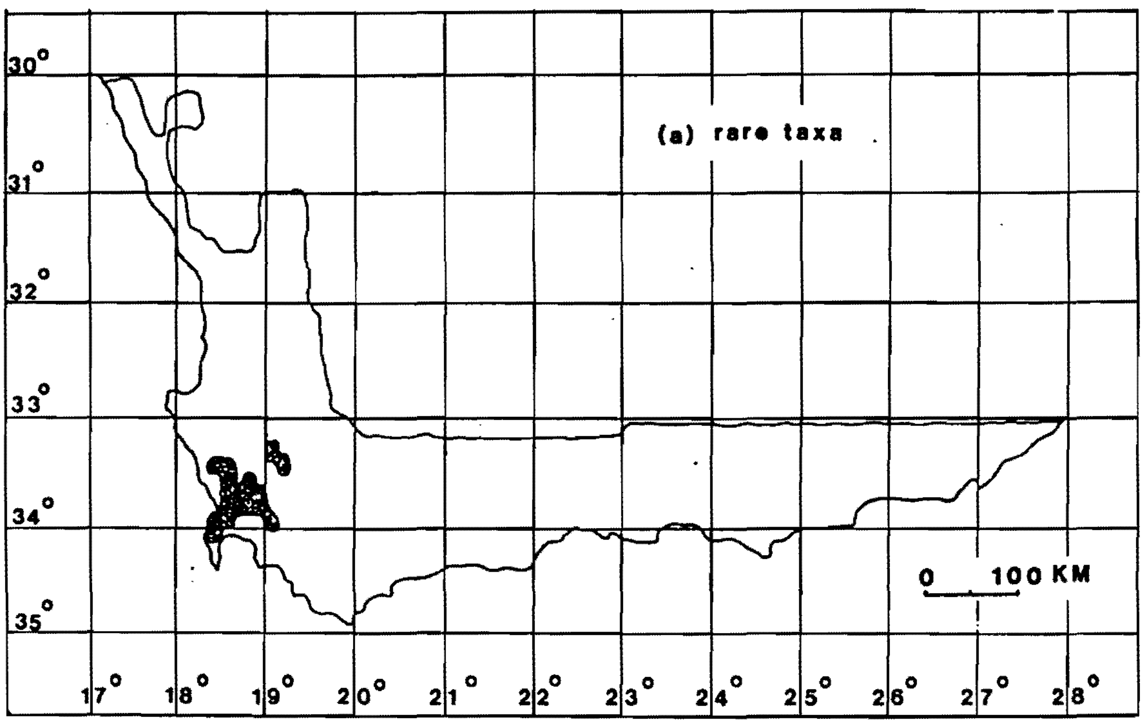
Diastella is concentrated in the south western Cape, south of 33°S and west of 19° 30'E, with the rare taxa constituting a major portion the total distribution range. It is thought that this genus has the most recent origin of all the Proteaceae (Rourke, 1976).

Orothamnus is restricted to 14 known populations occurring on the Kogelberg and Hermanus mountains. As this genus is monotypic, represented by the natural rare, *Orothamnus* *zeyheri* Pappe ex Hook. f.,it exhibits the largest area covered by rare taxa relative to the area covered by the genus itself. This is followed by *Diastella* with rare taxa covering 64 % of the distribution of the genus, *Sorocephalus* with 51 %, and *Mimetes* with 45 % of the genus distribution. All of these genera are represented by 13 or less taxa.

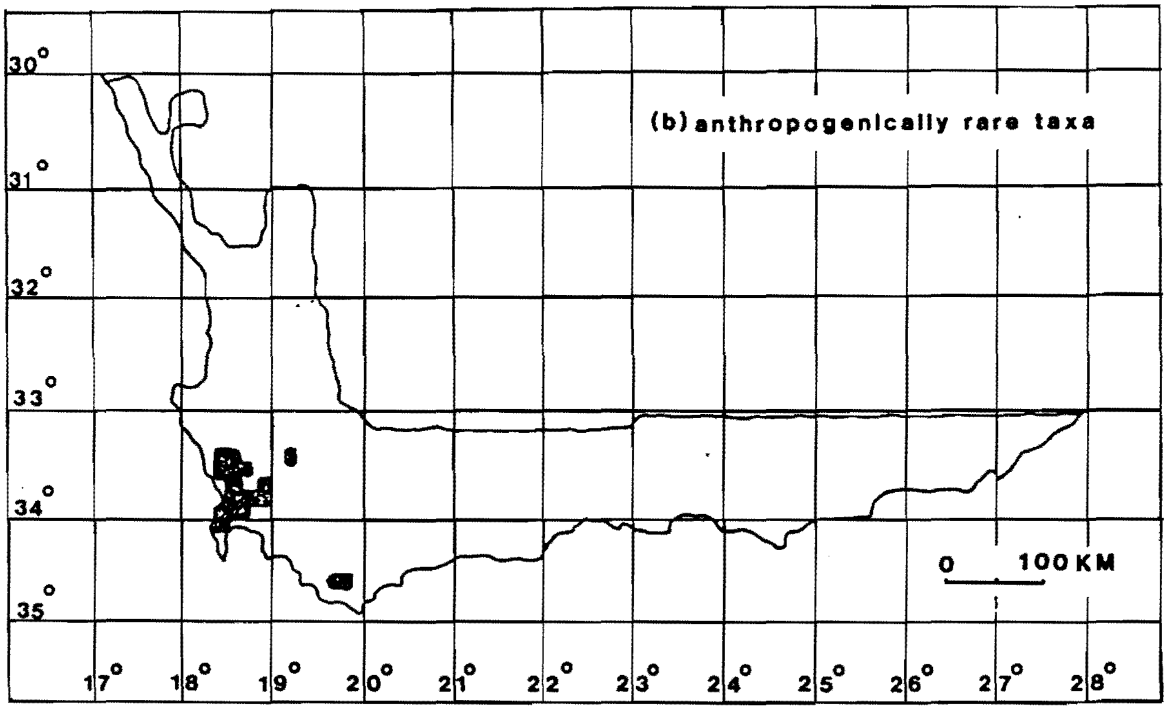
Areas of high concentrations of rare taxa

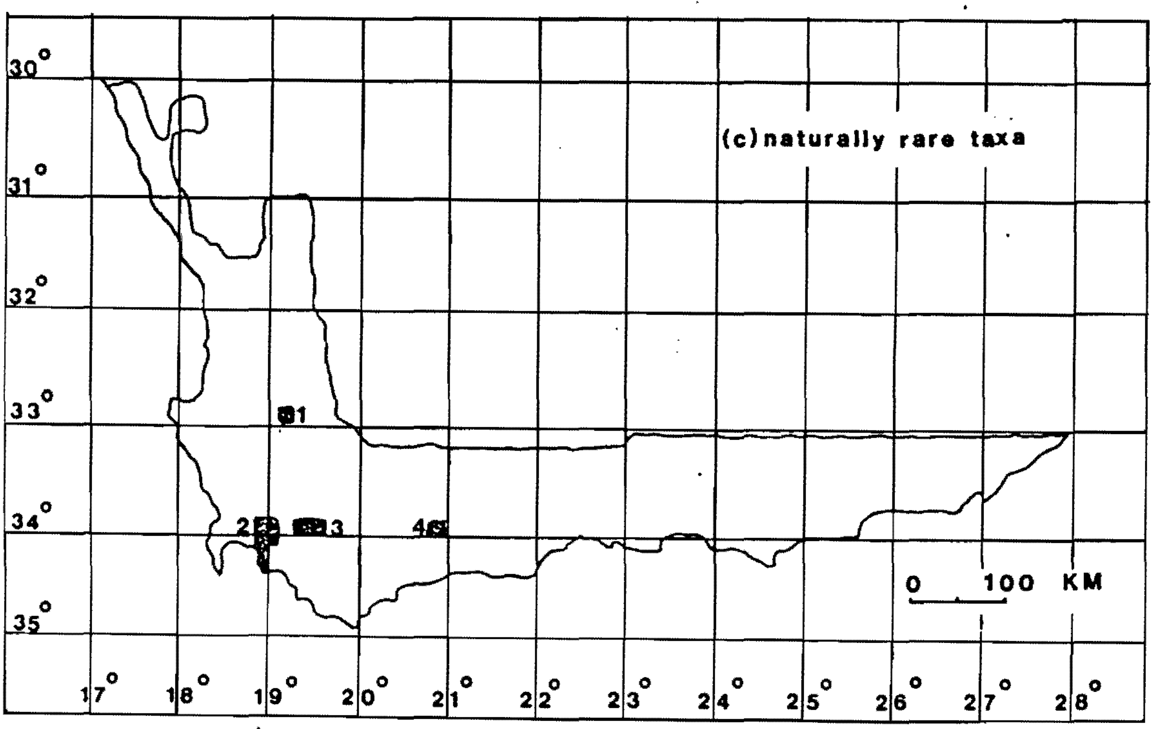
Linear regressions show that there is a relationship between the number of Cape Proteaceae taxa and the number of rare taxa per grid square (Fig 3). Therefore it was considered reasonable to assume that should a grid square lie above the 95 % prediction limit, it contains many more rares than could reasonably be explained by the regressions. When the number of rare taxa per grid were plotted against the total number of Proteaceae taxa per grid, 16 grid squares fell above the 95 % prediction limits (Fig 3a). These represent 3 % of the total area covered by Cape Proteaceae and are seen to lie in two areas (Fig. 4a). The first covers the northern half of the Cape Peninsula and stretches northwards to Contreberg, near Darling and inland to the foothills of the Drakenstein mountains. This area, some 2.5 % of the total distribution of the Cape Proteaceae, incorporates the greater portion of Cape Town and suburbs, Table Mountain, Blouberg, Durbanville, Tygerberg hills, Joostenberg, Dassenberg, Koeberg, Mamre flats, and Contreberg. The area not urbanized is intensely utilized for agriculture. Some 30 km^2 of Table Mountain has been declared a nature reserve. It is visited annually by some 200 000 tourists and day trippers (Greyling & Huntley, 1984). It is managed by the Cape Town City Council, who attempt to monitor the rare taxa and to control threats, particularly erosion near paths. This is the largest natural area remaining in this region delineated. Other natural areas include the many small hills on farms unsuitable for ploughing. In addition, the highest concentration of rare taxa occur in grid 3418 ABb (12 taxa), 3318 CDd (11 taxa), 3318 DCb (11 taxa) and 3318 DCc (10 taxa). Whereas this region must be considered a conservation priority, it is seen that land use is intense, making available conservation sites scarce and expensive. Many of the rare taxa exist at present on road verges,

FIG. 4. The distribution of grid squares found above the 95 % prediction limits of (a) all the rare taxa (from Fig.3a); b anthropogenic rare taxa (from Fig.3b); and (c) naturally rare taxa (from Fig.3c).



(a) rare taxa
30°
31°
32°
33°
34°
35°
0 100 KM
17°
18°
19°
20°
21°
22°
23°
24°
25°
26°
27°
28°


(b) anthropogenically rare taxa
30°
31°
32°
33°
34°
35°
0 100 KM
17° 18° 19° 20° 21° 22° 23° 24° 25° 26° 27° 28°


(c) naturally rare taxa
30°
31°
32°
33°
34°
35°
1
2
3
4
0 100 KM
17° 18° 19° 20° 21° 22° 23° 24° 25° 26° 27° 28°

traffic islands, race courses and hills unsuitable for ploughing. It is likely that, provided the existing small habitats remain intact, most of these taxa will continue to survive (See Chapter 1). The second area to exhibit an unusually high concentration of rares lies over the Elandsberg mountains (Fig. 4a). This area is under farming on the lowlands and forestry on the higher slopes. Included in this region is the Elandsberg private nature reserve which protects some 2000ha of fynbos on the lowlands. This region, higher up the mountain, is home for *Sorocephalus imbricatus* (Thunb.) R.Br., a taxa catergorised as endangered, which has a single population of two known plants remaining in the wild.

The regression of only those rare taxa classified as extinct, endangered, or vulnerable (Fig 3 b) yielded a similar result to that for all the rare taxa (Fig. 3a), producing 17 grid squares that were significantly different. There was one notable addition, the Elim flats, a unique limestone outcrop, on the south coast. the Elim flats are valuable pasturage for sheep as well as wheat production. This site was assessed by Cowling *et al.* (1988) and found to be extremely diverse and complex both in habitat and species. It is recommended for conservation.

The third regression (Fig. 3 c), shows the nodes of natural rares which are plotted in Fig. 4c and labelled 1 - 4. They cover 12 grid squares (2 % of the Cape Proteaceae distribution). Here each of the nodes lies within Weimark's (1941) centres of endemism: 1 lies in the North Western Centre, 2 lies in the Hottentots Holland Centre, 3 lies in the French Hoek Subcentre and 4 lies in the Langeberg Centre. Adamson (1958) warned that the concentrations of species imply neither centres of origin, nor survival from past southern migrations of the flora but rather that the conditions so suit the genus that it has been successful. This implies active speciation in these areas, a theory supported by Axelrod & Raven (1978). It is therefore possible that some of the naturally rare taxa are examples of such active speciation with a relatively recent origin and which have not as yet expanded their range. Although not under apparent threat, such centres of high concentrations of naturally rare taxa should be preserved as typical centres of endemism and perhaps speciation.

Conclusions

The distribution patterns of the different genera are characteristic for each genus. The distribution of the rares within each genus do not always reflect the full distribution range exhibited by the genus but tend to be clumped in restricted portions of the range, often occurring without the presence of non-rare taxa.

An analysis of rare plant distributions can be used to highlight areas of conservation priority. This study has recognised the need for additional conservation areas to be found in the south western Cape forelands, north of Cape Town. As this area is rapidly becoming increasingly urbanised, there is a need for conservation authorities to liaise with urban and regional planners so that some land can be conserved within the peri- urban zone. There is a need for a long term conservation plan for this region so that conservation is able to form an integrated part of its future development, rather than merely assessing the rate of loss of natural areas. The use of small nature reserves (Chapter 1) lends itself to the urban environment in terms of economics and should be encouraged.

The Elandsberg mountains and the Elim flats are also worthy of conservation input, although their needs are not as urgent. The four centres of endemism, as highlighted by the naturally rare taxa, are important areas of high species diversity and unique habitat variability. The conservation of such areas is essential in the long term dynamic viability and perpetuation of the fynbos biome.

It is felt that rare plant taxa are merely an indication of the true conservation status of the fynbos biome. Therefore if these symptoms are ignored, the prognosis for the successful conservation of this unique and diverse biome is at best poor. There is an urgent need for a regional conservation plan which is flexible and can be projected for long term development of this region. These results are specific for the family Proteaceae, however, it is likely that most of the other families will exhibit similar overall patterns.

Acknowledgements

This project was supervised by Professor E. J. Moll. Statistical Advice was supplied by L McNeill of Mathematical Statistics Department, U C T. C S I R provided financial support.

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CHAPTER 3

AN EXAMINATION OF THREATS TO RARE CAPE PROTEACEAE, SOUTH AFRICA AND TWO CORRELATED ECOLOGICAL FEATURES

INTRODUCTION

The Cape Floral Kingdom is a unique and diverse botanical entity which lies at the south western tip of Africa. It is restricted in area to some 90 000 km^2 (Bond & Goldblatt, 1984). It is approximated by the ecologically defined unit, the fynbos biome (as described by Moll & Jarman, 1984). The vegetation is typified by evergreen sclerophyllous shrublands (Moll & Jarman, 1984). The Cape Flora is represented by some 8504 species of seed plants of which 68 % are endemic (Bond & Goldblatt, 1984). Nearly 20% of the Cape Flora are considered to be rare or threatened (Hall & Veldhuis, 1985).

Ecologically, the family Proteaceae is one of three important diagnostic families of the fynbos biome, South Western Cape Province, South Africa (Taylor, 1978). Of 325 taxa known to occur, three have recently become extinct, and 121 are classified as rare, vulnerable or endangered (Chapter 1). Species ascribed the International Union for Conservation of National Resources (I.U.C.N.) status of extinct, endangered or vulnerable (as defined by Synge 1981) are species which, for the most part, have restricted distributions and occur in small populations, often declining in numbers.

Rare and threatened Proteaceae of the Fynbos Biome occur at sites known to be subjected to numerous and varied threats. An example of this is *Diastella proteoides* (L.) Druce, a species once widespread on the west coast forelands but now virtually exterminated through agricultural and urban development (Rourke, 1976). The aim of this investigation was to examine the potential threats facing the rare Cape Proteaceae and to record their occurrence at rare Proteaceae sites. In addition, ecological characteristics of the rare Proteaceae were compared to those of the rest of the family to assess potential correlation between ecological characteristics and rarity. Such parameters could be of predictive value in conservation management.

DATA BASE AND METHODS

In 1974 the South African Council for Scientific and Industrial Research (C S I R) established a rare plant monitoring programme which resulted in a taxonomic listing of all known rare taxa in the fynbos biome (Hall *et. al.*, 1984; Hall & Veldhuis, 1985). Much valuable data is held within this rare plant databank, particularly as unpublished field data sheets. These data provided the primary source of ecological information for this study. Further information was obtained from local botanists and additional fieldwork.

Reveal (1981) defines the term threat as the presence of an action which has the potential to disrupt or modify a site sufficiently to cause a species to decline in numbers. Potential threats observed at the sites of rare Proteaceae were listed from field data sheets of the threatened plant survey of the C S I R, available literature (Rourke, 1976, 1984), and field surveys. These threats were recorded as being present or absent at sites of each rare taxon and then totalled. It was not within the aims of this study to determine whether in fact the threat was currently adversely affecting the rare Proteaceae. However, the assumption that these were real or potential threats was based on a listing produced by Hall (1987).

Selected ecological parameters which might contribute to the rarity of certain taxa were measured in the field. These parameters included, amongst others, soil form, fire regenerative mode, flowering period, pollinating agent, seed dispersal agent, method of seed store, age of first flowering, age to senescence and population size and structure. Patterns within these parameters within the rare Proteaceae were observed relative to those for the family as a whole (Rebelo & Rourke, unpublished data). These patterns were analysed as frequencies using the Chi-square statistic (Zar, 1974) and interpreted in terms of the threats facing the rare Proteaceae.

RESULTS AND DISCUSSION

The most prevalent threats to rare Proteaceae are an unsuitable fire interval and the invasive Argentine ant, *Iridomyrmex humilis* which threaten 97 and 81 taxa respectively (Table I). Other

Table I: The frequency with which different threats are present at the sites of rare proteaceae are listed below

THREAT	NO OF TAXA THREATENED
fire	97
invasive Argentine ants	81
invasive alien plants	56
grazing	45
ploughing	41
trampling	21
bushcutting	16
wild flower picking	16
urbanization	11
fertilizer toxicity	7
pesticide toxicity	5
quarrying	5
flooding	2

major threats include invasive alien weeds (56 taxa threatened), flower picking (16 taxa threatened) and the agricultural threats of ploughing, grazing, trampling and bushcutting (Table I). Less common threats which affect between two and 11 taxa include urban expansion, fertilizer and pesticide runoff, quarrying and flooding.

Only two ecological parameters within the rare Proteaceae differed significantly from those observed in the family as a whole. The lifespan of the rare taxa was between 10 and 20 years,significantly lower than for the family as a whole (over 20 years), (X^2_2 = 61.91, P < 0.001).In addition, the pattern of seedstore showed significantly more myrmecochorous taxa among the rare Proteaceae (X^2_4 = 22.69, P < 0.001). It is notable that lifespan can be determined by fire interval and mymerochorous seedstore by the invasive Argentine ant, two of the most prevalent threats at rare Proteaceae sites. These features are discussed below.

Age to Senescence and Fire Interval

Most Proteaceae reach senescence when over 20 years old (Rebelo & Rourke, unpub. data), whereas most rare Proteaceae reach senescence between 10 and 20 years. That more rare Proteaceae than expected should have shorter lifespans can be shown to be a result of a history of inappropriate fire intervals. As in most other heathlands and fire maintained shrublands, there is a natural fire cycle in the Fynbos Biome. This regime is critical in determining community structure and diversity (Kruger, 1980). There is much controversy concerning the "natural fire interval" of the fynbos which, like the Australian heathlands, Californian chaparral and Mediterranean macchia, burns naturally at fire frequencies of between five and 40 years (Taylor, 1978; Bond *et al.*, 1984). Kruger and Bigalke (1984) indicated that the natural fire interval in fynbos is 30 years minimum. That a significantly high number of rare taxa have a shorter lifespan, suggests that this may be too high. Bond (1980) has shown that a long absence of fire in the Swartberg mountains has a detrimental effect on the regenerative ability of the fynbos when it eventually does burn. In serotinous species he observed that seedling regeneration was a direct function of the number of mature adults present at the time of burn. This indicated that seed for regeneration came only from flowerheads held on adult plants, and not from a seed store. Therefore, as seedling density is a function of the parent plant density, this will decline as the parent population dies from old age. Boucher (1981) observed that with a 34 year interval between fires, it was still possible for seedlings to regenerate in the rare *Orothamnus zeyherii* Pappe ex Hook.f. although an optimal number of seedlings regenerated when the population was burnt at 15 year intervals. Both these examples illustrate the need for the different taxa to burn before they reach the end of their lifespan so that optimal seed set is obtained.

Taylor (1978) describes how the early settlers attempted to control the wildfires at the Cape, the first wildfire laws being passed as early as 1687. The success of such legislation is unrecorded, although there must have been a detrimental effect on short-lived Proteaceae. Until 1970, state directorate of forestry policy excluded fire from the vegetation under its jurisdiction, which incorporated all natural vegetation in mountainous areas (Bands, 1977). Such an exclusion would select against short-lived taxa and may have contributed to the rarity of some taxa.

The present forestry management system involves a controlled intermittent rotational burning programme (Kruger, 1977) which uses a system of fire breaks (Kruger and Bigalke, 1984). Fire plays a central role in conservation because the natural fire regime is no longer possible due to urban, agricultural and forestry developments (Kruger, 1980). In this study inappropriate fire intervals were found to be the most common threat for 97 (78%) of the 124 rare Proteaceae (Table I).

Seed Store and the Argentine Ant

Of the 124 rare Proteaceae, 65 % are myrmecochorous in comparison to 53 % within the family as a whole. It is likely that the unusually high number of myrmecochorous rare Proteaceae is a result of the invasive alien Argentine ant, *Iridomyrmex humilis*. Bond & Slingsby (1984) state that myrmecochorous plants are particularly sensitive to changes in the dispersor community. The indigenous ants, *Anaplolepis custodiens*, *Anaplolepis steingroeveri*, *Camponotus niveosetosus* and *Pheidole capensis* collect seeds and remove them to their underground nests where they then eat the elaisomes. Thus the seed is efficiently removed from the soil surface. The nest cavity is strongly antibiotic and fungicidal(Beattie *et al.*, 1985) which protects the seeds. Acidic nest conditions also scarify the seed coat, assisting germination (Rebelo & Rourke, 1986). To some extent the seeds are dispersed away from the adult plants by the ants (Bond & Slingsby, 1984). The alien *Iridomyrmex humilis* is also attracted to the elaisome but feeds above ground and does not bury the seed (Bond & Slingsby, 1984). This alien ant displaces the above mentioned indigenous ants, and seedling recruitment may be diminished 50 fold (Bond & Slingsby, 1984). Such loss of seed reserves can significantly reduce the viability of the species in the long term and it is suggested that the Argentine ant has, in the past, contributed to the present rarity of the myrmecochorous taxa. This is still happening and more myrmecochorous taxa can therefore be expected to become rare in the near future. The Argentine ant must be considered a prime problem for successful conservation management of all rare myrmecochorous taxa.

Other threats

Although not as important as fire interval and the Argentine Ant, other threats present at sites of rare proteaceae nevertheless have the potential for considerable impact if not monitored.

Exotic woody plant species invade the fynbos remarkably easily and seriously alter the community structure (Richardson, 1985) and existing fire regime (Kruger, 1980). There are 56 taxa of Proteaceae which are choked by alien weeds. One of only two known populations of *Serruria furcellata* R.Br., has been completely displaced by invasive Australian *Acacia saligna* (Labill.) Wendl. (C. Burgers pers.com.). Much research is in progress in an attempt to design efficient control programmes (Macdonald & Jarman, 1984). The impact of ploughing threatens 41 rare Proteaceae, grazing threatens 45 , trampling threatens 21 and bushcutting threatens 16. Trampling and the resultant mechanical damage has been observed in the endangered

Leucadendron verticillatum (Thunb.) Meissner. (pers. obs.).

Seven rare Proteaceae are threatened by fertilizer runoff from neighboring fields. There are five rare Proteaceae threatened by pesticides. Pesticides used agriculturally drift onto indigenous vegetation providing a potential threat to pollinators and seed dispersors essential for the completion of the life cycle of the indigenous plants.

Wild flower picking directly affects 16 rare Proteaceae. Picking is most prevalent in the southern Cape near Bredasdorp and is an expanding trade worth millions on the international market (Vogts, 1982). The free onboard value for protea blooms for 1985 was R7 886 000, one third of the total income from the exportation of cut flowers (figure from monthly trade abstracts, 1985). In addition to protea blooms, some species are picked to provide green filler for bunches of flowers. For example, *Spatalla ericoides* E.Phillips is picked for providing green filler (M Simpson pers. com.). This plant is 0.25m tall at maturity and the whole plant is picked. Because this species matures between five and 10 years of age, it cannot regenerate rapidly enough to counter excessive picking at present. This plant species has the I.U.C.N. status of endangered and there are an estimated 500 plants remaining. The free onboard value of such green filler exported during 1985 was R2 910 500 (figure from the monthly trade abstract 1985). *Leucadendron platyspermum* R.Br. (status vulnerable) is a serotinous species, also from the southern Cape. The phenomenon of serotiny permits both an accumulation of seed reserves in the canopy of the plant and fire induced seed release at a time when predation and competition are reduced and resource levels are high (Bond, 1985). This plant is picked for the dried seed cones which are used in flower arrangements. When the cones are picked the seeds are still firmly held and are only released upon drying in the drying sheds, resulting in a total depletion of seed reserves in the wild. These two examples emphasize the negative attributes of wild flower picking.

Urbanization threatens the habitats of 11 rare Proteaceae. *Leucadendron levisanus* (L.) Bergius and *Serruria trilopha* Salisb. ex Knight are two of the most severely affected species at present. Both of these are endangered. With the rapid expansion and development of suburbia, the prognosis for the survival of such species seems poor. Small reserves might be the only salvation (Chapter 1). *L. levisanus* has one population in the centre of a racecourse and a second in a traffic island along a major roadway. Both these populations are surviving unaided and relatively undisturbed. Because rare Proteaceae require such small areas, it might be possible to conserve other rares similarly threatened by urban expansion. However, liaison between conservation authorities and urban and regional planners, prior to development, will be essential.

Five rare Proteaceae have had part of their habitat permanently destroyed by quarrying. *Serruria incrassata* Meissner and *Leucadendron thymifolium* (Salisb. ex Knight) Williams, previously known from the Klipheuwel quarry site near Malmesbury on the west coast foreland, are two such species.

Only two species are threatened by flooding. Because of the country's increasing water needs the two known habitats of *Spatalla prolifera* (Thunb.) Salisb. ex Knight (status endangered) and the five known habitats of *Protea angustata* R. Br. (status vulnerable) will be flooded. Unless suitable alternate dam sites are available the preservation of these two species in the wild will be impractical.

CONCLUSION

In conclusion it should be noted that the ecological parameters of age to senescence and method of seed store are significantly different in the rare taxa from the family as a whole. This is a result of the unnatural fire regime and the increasing presence of the alien Argentine ant. It is imperative that conservation managers are made aware of these problems and direct their policy according to the specific vulnerability of the threatened taxa. The other threats facing the rare Proteaceae fall within two groups; those that might be controlled and monitored such as flower picking, agriculture and alien plant infestations; and those which are inevitable such as urban development, flooding and quarrying. All rare Proteaceae sites need careful and regular monitoring and a suitable long term management programme determined, whether it be *in* or *ex situ*.

ACKNOWLEDGEMENTS

The author thanks A.G. Rebelo and J.P. Rourke for the use of unpublished data of characteristics of the family Proteaceae and for computer analysis. Professor E.J. Moll and Dr J.P. Rourke supervised this project. Financial support was provided by the C S I R.

SUMMARY

This paper attempts to isolate ecological parameters that are significant in terms of conservation priorities for management of rare plant taxa. In this investigation of Proteaceae a significantly shorter lifespan has been noted amongst the rare taxa. This reflects an artificially imposed fire regime which was not sufficiently similar to the natural regime which has now been excluded for almost 300 years. The rare taxa exhibit an exceptionally large number of mymerochous taxa indicating the vulnerability of such taxa to this threat. As the forestry fire policy is now more flexible, the Argentine ant should be considered the most serious threat and is a key issue for conservation managers before the situation deteriorates further. Other threats observed at rare Proteaceae sites, although not showing any relationship to particular ecological features, are also examined. These include alien plant invasions, agriculture and wild flower picking, which can be monitored and controlled. Others such as quarrying, urban sprawl and flooding are inevitable in the growth of a fast developing country, and cannot be halted so demand an *ex situ* conservation programme if they are to be maintained.

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SUMMARY AND CONCLUSIONS

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Of 325 taxa of Proteaceae in the fynbos biome, 124 have been ascribed as the IUCN status of extinct (3 taxa), endangered (33 taxa), vulnerable (29 taxa) and naturally rare (59 taxa). None were considered indeterminate or insufficiently known. The comparison of the status ascribed to the rares differed considerably from the previous status on most of the dossiers, as held by the C S I R rare plant data base. There were 24 additional taxa, 28 deletions, and 34 with an altered status. The main reasons for these changes are taxonomic updating, increased information by pooling knowledge of the workshop participants, and altered threat regimes. This result is significant as it underlines the need for constant monitoring of rare plants populations.

Rare Cape Proteaceae are characterised by small populations, few individuals per taxa, and restricted geographical ranges. For example 59 taxa are restricted to one or two populations, 31 are restricted to 500 or fewer individuals, and 63 have a range of $5km^2$ or less. When these population parameters are viewed in combination it is seen that 53 taxa are both restricted to a range under 5 km^2 and to only one or two populations. These taxa are particularly vulnerable to relatively minor impacts, and extinction is likely to be a sudden and unpreventable occurrence. In the light of these characteristics concluded from the population parameters of the rare Proteaceae, a system of numerous small reserves as little as 5 km^2 would be most appropriate for best conserving rare Proteaceae. The ideal would be on reserves, each representing a unique habitat and,to facilitate management, each should be as close as possible to other reserves. If one carefully plots the distribution of the rare Proteaceae it becomes clear that such a chain of small reserves is feasible, the specific size of each reserve would be determined by the minimum population requirements for the species in that reserve. This minimum population size needs to be determined for all Proteaceae species. This project has shown that to manage rare plants a good knowledge of the population parameters is a priority. These populations need constant monitoring and management procedures need to be constantly revised because of the dynamic nature of these rare taxa. This allows for an accurate assessment of the current status and identification of any changes, whether these are anthropogenic or natural.

The distribution of the rare Cape Proteaceae was compared to that of all the Cape Proteaceae. In addition the naturally rare and threatened taxa were considered separately. The Proteaceae occupy 65% of the total area of the fynbos biome, of which 3% contain rare taxa. A comparison, using linear regression analysis, of the rare taxa distribution and the total Proteaceae distribution show that 16 of the 150 km^2 grid squares contain more rare taxa than expected ($r = 0.78$). These grids lie in two areas, one covering the northern portion of Cape Town and the lowlands to the north as far as Contreberg, and the second lies in the Elandsberg Mountains. The first area is considered of prime importance for immediate conservation input, particularly for urban and regional planners, due to the rapid development and expansion in the area. An examination of only the threatened taxa, shows that 17 grid squares contain more rares than expected. Most of these lie in the area described above. An important addition is the Elim flats on the south coast. Here unique and diverse communities are under threat from agricultural expansion. The naturally rare taxa show nodes not explained by the regression, lying over the areas generally considered as endem centres. This indicates that such areas are unique centres of endemism and require increased conservation.

Threats were recorded from rare Proteaceae sites and ecological parameters were correlated with rarity. An inappropriate fire interval has adversely affected 97 taxa and the Argentine ant, *Iridomyrmex humilis*, 81 taxa. The rare taxa exhibit a significantly shorter lifespan of 10-20 years when compared to the family ($X^2 = 61.91$, $P < 0.001$). As lifespan is completely controlled by fire interval in the fynbos biome, this means that the interval in the past has been inappropriate, largely due to the fire exclusion policy, causing Proteaceae taxa with short lifespans to be selected against. The present policy is more flexible and so accommodates short lifespans better and an inappropriate fire interval is unlikely to be a threat in the future. The rare taxa exhibit a significantly higher number of myrmecochorous taxa when compared to the family Proteaceae (X^2 = 22.69, P = 0.001). The Argentine ant competes with indigenous ants for Proteaceae seeds with elaisomes. The Argentine ant discards the seed on the surface of the soil unlike the indigenous species which remove the seed to underground stores which are ideal incubators of these seeds. The removal of the Argentine ant is essential before all of the 184 myrmecochorous Proteaceae taxa are depleted. Other serious threats include agriculture, flower picking and urban development.

The results of this thesis are specific for Proteaceae. It is likely that similar results will be obtained for most of the other typical Cape families. Preliminary unpublished results for Restionaceae already support this. This thesis has highlighted the suitability of small nature reserves which are economically attractive and has shown that a high management input is not necessarily required. The Argentine ant is considered to be of prime importance in terms of management of conservation sites. An overall management plan for the fynbos biome, which clearly states the aims, objectives and proposed management techniques, is long overdue for this unique floral kingdom. Such a plan, drawn up with the aid of ecologists and managers should be a priority before the tenuous state of so many unique plants is further depleted.

ACKNOWLEDGEMENTS

ACKNOWLEDGEMENTS

There are many people to whom I am most grateful for their assistance in different ways. Firstly I thank Professor E J Moll, Botany U C T for his supervision of this thesis and for his constant encouragement and understanding. Dr J P H Rourke, Compton Herbarium, Kirstenbosch, assisted with the initial supervision of this project and offered many useful ideas.

Professor W Zucchini and Miss L McNeill, both of Mathematical Statistics U C T, provided much needed and appreciated statistical advice.

Mr A G Rebelo, Percy Fitzpatrick Institute U C T, assisted with the computer analysis of the data.

I am grateful to my husband, Chris, for his support and sharp criticism of numerous drafts of manuscripts and for proofreading the thesis. I thank my colleagues of the ecolab for their stimulation and discussion.

Financial support is gratefully acknowledged from C S I R (F R D).